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September 29, 2015

Ms. Brenda Edwards
U.S. Department of Energy
Building Technologies Program, Mailstop EE-5B
1000 Independence Avenue SW
Washington, DC 20585-0121

Re: Energy Conservation Standards for Residential Boilers; Proposed Rule
Docket Number EERE-2012-BT-STD-0047

Dear Ms. Edwards:

On July 1, 2015 the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) submitted comments in response to the Department of Energy's (DOE) notice of proposed rulemaking (NOPR) regarding amended efficiency standards for residential boilers issued in the March 31, 2015 *Federal Register*. In those comments we noted that the NOPR analysis has not accurately assessed the number of replacement installations that will require some work of the venting system and the cost of that vent work at the minimum AFUE levels proposed by DOE. We informed DOE that AHRI had contracted the Gas Technology Institute (GTI) to study the performance of vent systems when connected to boilers operating at the efficiencies considered in the DOE analysis. This research project has been completed and the GTI report "The Impact of Increasing Residential Boiler Efficiency Levels on Vent Performance" is attached.

AHRI's previous comments detailed our concerns with the widely varying characteristics of venting systems to which existing boilers are connected and the manufacturer's awareness of the need to have boiler designs that are robust enough to operate safely and properly when connected to these venting systems when the existing boiler is replaced. We presented our position that boilers with AFUE ratings in the 83.5% to 87% range result in near condensing installations. This GTI study, which analyzed the AFUE levels of 83%, 84% and 85% validates that position and shows how the potential for unacceptable wet times occurring in various parts of the vent system increases, particularly at the 84% and 85% AFUE levels. As explained in the report, the "wet time" limits are values that have been used to establish the coverage for properly sized and configured vent systems for atmospheric gas-fired boilers in the National Fuel Gas Code. When the Vent-II analysis shows wet times exceeding these limits, it is an indication of excessive condensation which increases the potential for condensate-induced corrosion and subsequent vent system failure.

From the perspective of this rulemaking at least two aspects of the analysis must be redone. DOE must analyze the changes in product designs and installation instructions that manufacturers will make at the higher proposed AFUE levels to address this increased potential for excessive condensation to occur in existing vent systems. The design change is not just the simple addition of more heat exchanger area. We have already noted that the proposed level for gas boilers in the NOPR will likely cause a majority of models to use a fan-assisted design. It may also cause manufacturers to specify that parts or all of the venting system should have water-tight joints and use materials that are corrosion resistant. Also DOE must analyze the added cost to rework or replace existing venting systems in replacement installations. The results of the analysis done by GTI show that at an 84% or 85% level the potential for excessive wetting in the vent system increases. To address this increased potential for excessive condensate in the vent system, the specifications for the size, configuration, and materials for venting systems appropriate for models at those efficiency levels may be very different than the requirements which governed the existing vent system in a home. In such cases there will be added cost to rework or replace the vent system. This circumstance will apply to a much larger percentage of installations than assumed in the current DOE analysis.

We request DOE to review this report and reassess the cost of boilers at the minimum AFUE levels proposed in the March 31, 2015 NOPR. We believe that a proper assessment will show that for many consumers the total installed cost of a higher efficiency boiler will outweigh the value of the energy savings provided by that boiler.

There is one other technical issue which we had been inadvertently omitted in our earlier comments. The NOPR proposes that oil-fired steam boilers meet the same minimum AFUE standard as oil-fired hot water boilers. This is not a technically reasonable proposal. To this point different AFUE levels have been specified for steam and hot water boilers. That is still the case for the amended standards being proposed for gas fired boilers. The residential boiler market is not large. The economies of scale that exist in the residential furnace market are not available to the manufacturers of residential boilers. It is very common to design a residential oil fired boiler model that can operate as either a steam boiler or a hot water boiler depending on the boiler trim applied to the basic design. For an oil fired boiler that is marketed as either a steam boiler or a hot water boiler, the AFUE for the steam boiler version will always be lower than the hot water version of that same design model. It is not economic for a boiler manufacturer to design and have separate tooling for an oil fired steam models and an oil fired hot water models. Pattern equipment costs alone can get close to a half of million dollars. The proposed minimum 86% AFUE for steam oil-fired boilers is forcing an economic burden on the manufacturer greater than the NOPR estimates because it will require either the development of separately designed steam boiler models or substantial changes to the design of hot water models to raise the AFUE above 86% so that when the steam version of that design is tested it can comply with the proposed 86% minimum. Neither option is justifiable; DOE should continue to specify a different, lower AFUE level for oil fired steam boilers as compared to that specified for oil -fired hot water boilers.

Respectfully Submitted,

Frank A. Stanonik
Chief Technical Advisor

FINAL REPORT

GTI PROJECT NUMBER 21832

The Impact of Increasing Residential Boiler Efficiency Levels on Vent Performance

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Scope of Work

Introduction

The National Fuel Gas Code (ANSI Z223.1/NFPA 54 2012) (NFGC) provides vent sizing guidelines for Category I atmospheric and fan-assisted appliances that result in a safe and durable vent system design. The tables were developed with the primary assumption that an appliance vent would not operate outside of its wet-time limits; that is, the vent would be wet for a certain amount of time each cycle up to a certain limit and then operate in a dry mode for the remainder of the cycle. As appliance efficiency increases, the flue gasses spend more time below the dew point temperature, the length of the wet time increases and there is the potential that the wet time limit will be exceeded and the vent will fail prematurely due to corrosion.

Objective

The objective of this project is to determine the effect of increasing boiler efficiency levels above the current NAECA minimum on vent performance. Specifically, the project will investigate increasing wet times in the vent and masonry chimney compared to current acceptable practice in the NFGC.

Scope

The scope of the project is to perform VENT-II analyses on residential atmospheric boilers in several configurations to determine the wet time in the appliance connector and vent. The wet time in the appliance connector is compared to (1) the 3.8 minute wet time limit used in the NFGC tables to avoid condensate-induced corrosion, and (2) the 9.8 minute boiler cycle time in the ASHRAE 103 standard. For the masonry chimney case, the wet time limit from the NFGC was used - wet time exceeding the boiler cycle time after 12 hours of continuous cycling. Three boiler time/temperature curves provided by AHRI were used as the basis for the study. The curves were adjusted for common CO_2 levels and for each steady-state efficiency level to be modeled.

A list of parameters studied is provided below:

- Atmospheric boilers with vent (stack dampers) at 3 capacities and 4 steady state efficiency/AFUE levels
- Vent design – one story house with boiler in the basement
- Boiler vented alone
- Masonry chimney and, B Vents, with single wall and B vent connectors
- Sensitivity of modeling assumptions

Wet Time Limits

From VENT-II and Venting Tables Research

The Category I venting tables in the NFGC were developed based on the ability of the appliances to avoid condensate-induced corrosion in the vents and to be able to provide sufficient buoyancy to vent the flue gasses. The natural draft sizing tables were originally developed in the 1950's and remain unchanged in the code. The fan-assisted venting system tables were developed in the

1980's to address increasing efficiencies and the emerging use of fan-assisted combustion systems.

In GRI-01/0128 *A Synopsis of Gas Appliance Venting Research and Its Relevance to Higher Efficiency Gas Furnaces and Boilers* (Paul, 2002):

- Single Appliance Venting Tables – Minimum vent capacities were based on the connector (single or double wall) drying out within 3.8 minutes after the start of the 3rd appliance cycle.
- Average furnace cycling was 3.87 minutes on and 13.3 minutes off.

Three wet time limits were set for this study. In all cases, any wet time exceeding the limits is a failure. Boiler vent connectors were evaluated at 3.8 minutes into the third appliance cycle and 9.8 minutes into the third appliance cycle to cover both the NFGC cycling rate (for furnaces) and the ASHRAE and DOE test procedure cycling rate (for furnaces and boilers). The masonry chimney was evaluated at 12 hours of continuous cycling. If the connectors or vents were wet beyond those time limits, the appliance fails to dry out within the wet time limits.

Analysis

Assumptions

- One story houses with boilers in the basement were modeled. The vent height was 16 feet and the lateral varied according to the rule provided in this report. For masonry chimneys, only internal masonry chimneys were modeled.
- Inside and outdoor temperature conditions matching those used to develop the venting tables were used.
- Boiler cycle times from Table 7 of ASHRAE 103 – 2007 are 9.68 minutes on and 33.26 minutes off, for a total cycle time of 42.94 minutes. Furnace cycling time is 3.87 minutes on and 13.3 minutes off. Boiler cycling times were used for the VENT-II analysis.
- The NFGC venting tables minimum capacities were developed based on dryout in the connector after 3.8 minutes of the third appliance cycle. Dryout was evaluated in this project based on both 3.8 minutes and 9.68 minutes into the third appliance cycle. A violation if the wet time limits indicates that the boilers are not compliant with the tables and thus the NFGC – extended wet times increase the likelihood of vent corrosion failure.
- For masonry chimneys the criteria was based on dryout of the vent connector after 3.8 minutes into the third appliance cycle or a clay tile liner drying out after 12 hours of continuous cycling.
- For the modeling, a 1 ft. connector rise from the appliance was used and a lateral length of no more than 18 inches per inch of vent diameter was used: 10 ft. of lateral for Type B vents (permitted by the code) and 3 ft. of lateral for masonry chimney connectors.
- Assumption that steady-state efficiency is 0.3% higher than AFUE (rule of thumb provided by AHRI).

A more comprehensive list of assumptions is provided in Appendix A.

VENT-II Modeling

Three atmospheric boilers were modeled based on time temperature curves and flue gas data provided by the manufacturer.

Table 1, below shows the combustion characteristics for the boilers from the data received.

Table 1. Boiler Characteristics

Boiler Character-istics	Model Identifier	Input, Btu/hr.	CO2, %	Flue Gas Temp, F	Stack Gas Temp, °F	Steady State Efficiency	Category
Boiler 1	3SEC-BAF-NAT	71,051	8.21%	366	292	82%	I
Boiler 2	9SEC-BAF-NAT	285,978	8.93%	384	282	82%	I
Boiler 3 - turndown	9SEC-BAF-NAT2	283,437	9.03%	378	299	82.3%	I

Three typical boilers were developed from the manufacturer's data for modeling purposes. The CO_2 levels were first modified to 8% CO_2 make the boilers representative of the atmospheric products in the marketplace by using the GTI combustion calculator. The resulting excess air level was 43.4% across all the products and the flue gas maximum temperature was recalculated.

For the wet time analysis, the efficiency of the boilers was adjusted from the as-received levels to 82% AFUE, 83% AFUE, 84% AFUE, and 85% AFUE using the GTI combustion calculator and the following approach: first, the assumption was made that steady state efficiency is 0.3% greater than AFUE, based on AHRI input. Then the flue temperature was calculated to match the new CO_2 percentage and steady state efficiency: 82.3%, 83.3%, 84.3%, and 85.3%. Note that calculating the peak flue temperatures this way is based on the assumption that the increase in efficiency will be achieved by adding heat exchanger area without impacting the combustion characteristics of the boiler.

The resulting numbers used for VENT-II modeling are provided in Table 2 and Table 3, below. Although the boiler CO_2 and excess air levels are now the same for each efficiency level, the capacities and time/temperature curves used in the VENT-II analysis are still unique to each boiler.

Table 2. Boiler Characteristics at 8% CO_2

Boilers at 8% CO_2	**AFUE (0.3% below SSE), %**	**Steady State Efficiency from Combustion Calculator, %**	**CO_2, %**	**Excess Air, %**	**Flue Gas Temp, F**
Boiler 1	81.5%	81.8%	8.00%	43.4%	366
Boiler 2	81.0%	81.3%	8.00%	43.4%	384
Boiler 3	81.1%	81.4%	8.00%	43.4%	378

Table 3. Calculated Boiler Flue Gas Temperatures by Efficiency Level

Calculated	**AFUE (0.3% below SSE), %**	**Steady State Efficiency, %**	**CO_2, %**	**Excess Air, %**	**Flue Gas Temp, °F**
82% AFUE					
All Boilers	82%	82.3%	8.00%	43.4%	348
83% AFUE					
All Boilers	83%	83.3%	8.00%	43.4%	312
84% AFUE					
All Boilers	84%	84.3%	8.00%	43.4%	279
85% AFUE					
All Boilers	85%	85.3%	8.00%	43.4%	242

Stack gas time-temperature curves were provided from a manufacturer. The curves were modified to fit the ASHRAE 103 AFUE cycle rate of are 9.68 minutes on and 33.26 minutes off, for a total cycle time of 42.94 minutes. The stack data and fit are provided in Figure 1, below, for Boiler #1.

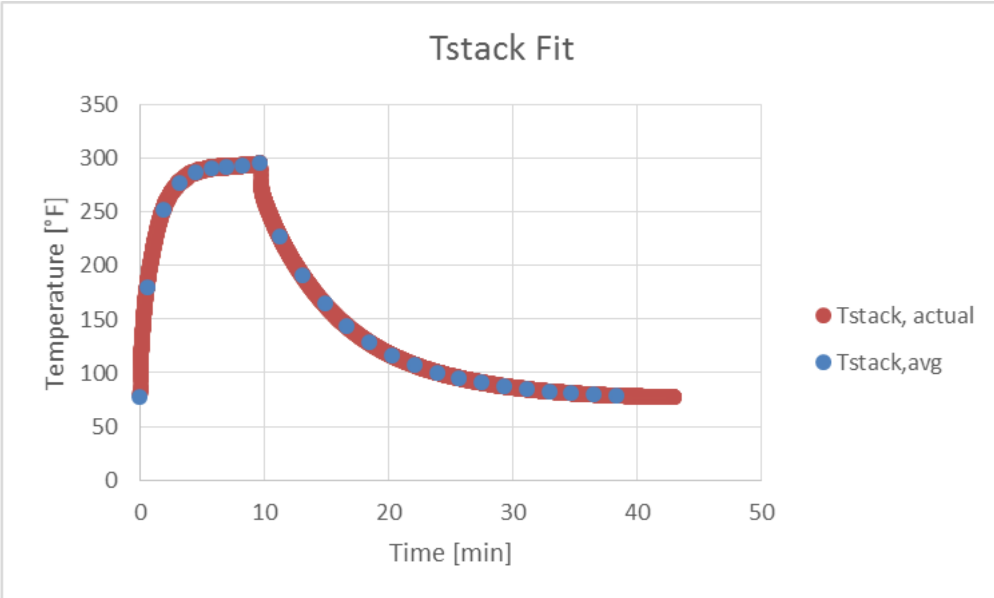

Figure 1. Stack Temperature Fit

The stack gas data was then scaled to the max flue gas temperature provided to develop the flue gas time temperature curve required for VENT-II analysis. The curve was also reset so the minimum flue gas temperature matched the 120 °F value commonly found in cycling boilers. Finally, the time temperature curves were scaled to the flue gas temperatures calculated for each AFUE level. The scaled Boiler # 1 curves by AFUE are provided in Figure 2, below.

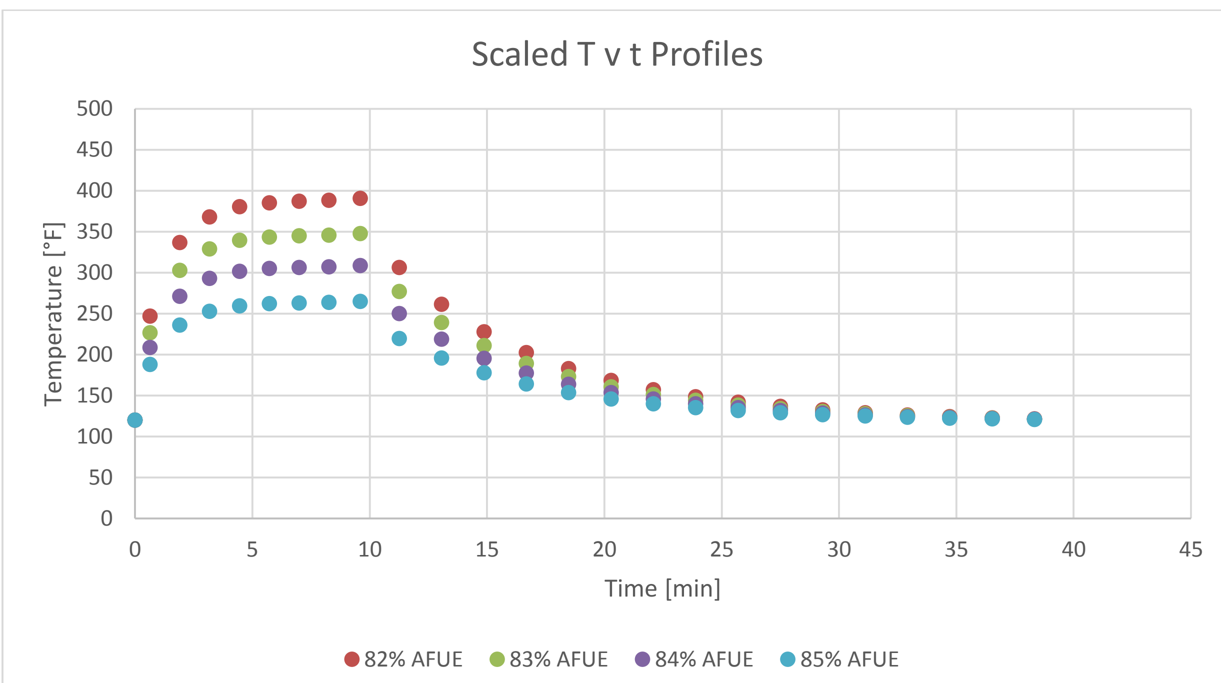

Figure 2. Scaled Flue Gas Time Temperature Profiles by AFUE

Type B vents with Type B vent connectors and single wall vent connectors were studied. A 10 ft. lateral length was assumed, well within the 18 inches of lateral length per inch of vent diameter allowed by the code.

For masonry chimneys, the use of a vent damper restricts the installation of boilers (NFGC Section 13.1.1) in some cases. Boiler 1 could not be installed in an interior masonry chimney without relining the chimney, so that case was dropped from the chimney study. Although the code allows the use of a 10 ft. vent connector for masonry chimneys, all of the chimneys studied had excessive wet times with the vent damper at 10 ft. A 3 ft. connector was used to determine if relocating the boiler closer to the chimney would be an acceptable alternative that would produce acceptable we times.

Results

The following figure and tables provide the results of the VENT-II Version 5.3 analysis. Figure 3 provides the basic layout of the appliance, vent connector, and vent or chimney. The vent connector is the length of pipe between the appliance and the vertical section of the vent or chimney. The vent (or vertical vent) relates to the vertical section of the vent that terminates outdoors. Unless otherwise indicated the vertical vent is a Type B metal vent. Chimney refers to the use of brick or masonry as the materials used for the vertical vent.

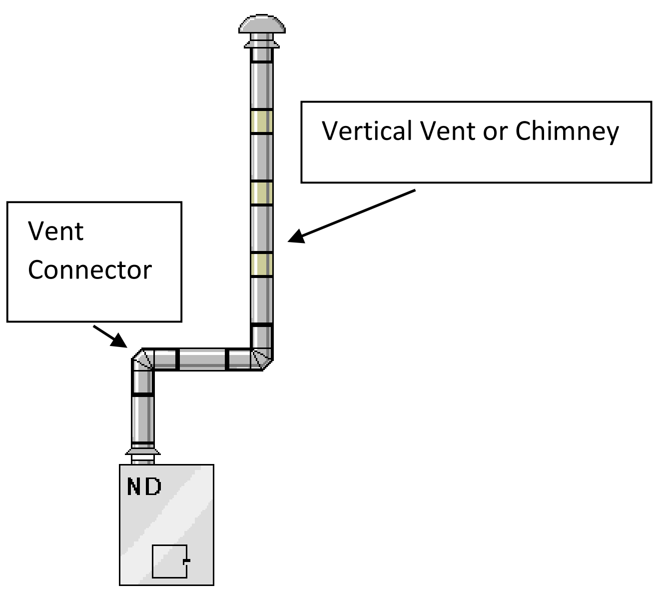

Figure 3. Vent Schematic

In the tables, shaded cells exceed the indicated wet time limits as follows:

Shading	
	Exceeds 3.8 minute limit
	Exceeds 9.6 minute limit
	Exceeds 12 hour limit for masonry chimney – wet for 41 minutes

Table 4 through Table 6 provide results for the three boilers when vented with a Type B vent connector into a Type B vent or a masonry chimney. Efficiencies from 82% AFUE through 85% AFUE were evaluated at a minimum flue temperature of 120 °F. Note that the wet time limit of 3.8 minutes is exceeded for all three boilers at 85% AFUE for Type B vertical vents and for all masonry chimney configurations starting at 83% AFUE.

Table 4. Boiler 1 - Type B Connector and Masonry Chimney Wet Times

Boiler 1 - Type B Connector and Masonry Chimney Wet Times					
Properties	AFUE	82%	83%	84%	85%
	Flue Min Temperature [°F]	120 °F	120 °F	120 °F	120 °F
Connector Wet Time, min	To a Type B Vent	2.7	3.0	3.7	5.0
	To a Masonry Chimney	NA*	NA	NA	NA
Vertical Vent Wet Time, min	Masonry Chimney	NA	NA	NA	NA

*NA means not allowed by the NFGC.

Table 5. Boiler 2 - Type B Connector and Masonry Chimney Wet Times

Boiler 2 - Type B Connector and Masonry Chimney Wet Times					
Properties	AFUE	82%	83%	84%	85%
	Flue Min Temperature [°F]	120 °F	120 °F	120 °F	120 °F
Connector Wet Time, min	To a Type B Vent	2.0	2.7	3.0	4.0
	To a Masonry Chimney	2.3	2.7	3.3	4.7
Vertical Vent Wet Time, min	Masonry Chimney	>45	>45	>45	>45

Table 6. Boiler 3 - Type B Connector and Masonry Chimney Wet Times

Boiler 3 - Type B Connector and Masonry Chimney Wet Times					
Properties	AFUE	82%	83%	84%	85%
	Flue Min Temperature [°F]	120 °F	120 °F	120 °F	120 °F
Connector Wet Time, min	To a Type B Vent	2.3	2.7	3.3	4.3
	To a Masonry Chimney	2.7	3.0	3.7	5.0
Vertical Vent Wet Time, min	Masonry Chimney	>45	>45	>45	>45

Table 7 provides a sensitivity analysis on the flue temperature assumption being used for all the 85% AFUE cases. Cycling boilers may maintain a circulating water temperature above 120 °F and thus the starting flue temperature for a cycle may be at 120 °F. Alternatively, boilers may be controlled such that a circulating water temperature is not maintained and the boiler flue temperature may drift down during light load. A temperature of 100 °F was chosen for a sensitivity analysis. The results in the table show that the lower flue temperature assumption results in excessive wet times under all 85% AFUE cases. The approach to controlling the boiler circulating water temperature may impact the durability of the vent system at these efficiency levels. (Note that the masonry chimney fails the wet time criteria for boilers 2 and 3 at 85% AFUE and 120 °F flue temperature as shown in Table 5 and Table 6.)

Table 7. Sensitivity: Flue Temperature Assumption

Sensitivity: Flue Temperature - Connector Wet Times				
Properties	Boiler	Boiler 1	Boiler 2	Boiler 3
	AFUE	85%	85%	85%
	Connector Material	Type B	Type B	Type B
	Flue Temperature [°F]	100 °F	100 °F	100 °F
Connector Wet Time, min	*To a Type B Vent*	5.3	4.3	5.0
	To a Masonry Chimney	NA	5.3	5.7
	Flue Temperature [°F]	120 °F	120 °F	120 °F
Connector Wet Time, min	*To a Type B Vent*	5.0	4.0	4.3
	To a Masonry Chimney	NA	4.7	5

Table 8 shows the sensitivity to the choice of vent connector for the Type B vent case. Single wall connectors are commonly used in boiler installations, especially with masonry chimneys. The table shows that single wall connectors will fail the wet time limits for all the efficiencies studied and Type B connectors are expected to fail only the 85% AFUE case.

Table 8. Sensitivity: Vent Connector – Type B Vent (case not modeled)*

Sensitivity: Vent Connector - B Vent					
Properties	AFUE	82%	83%	84%	85%
	Common Vent Material	Type B	Type B	Type B	Type B
	Connector Material	Single Wall	Single Wall	Single Wall	Single Wall
Connector Wet Time, min	*Boiler 1 Wet Time [min]*	5.7	7.3	10.3	*
	Boiler 2 Wet Time [min]	4.7	5.7	8.0	*
	Boiler 3 Wet Time [min]	5.0	6.3	8.3	*
	Connector Material	Type B	Type B	Type B	Type B
Connector Wet Time, min	*Boiler 1 Wet Time [min]*	2.7	3.0	3.7	5.0
	Boiler 2 Wet Time [min]	2.0	2.7	3.0	4.0
	Boiler 3 Wet Time [min]	2.3	2.7	3.3	4.3

Table 9 provides the same sensitivity analysis for masonry chimneys. Again, all single wall connector cases fail for all efficiencies studied. The Type B connectors pass the 82-84% cases but fail the 85% case. However, recall from Table 6 that the masonry chimney itself fails the wet time criteria for all cases.

Table 9. Sensitivity: Vent Connector - Masonry Chimney (case not modeled)*

Sensitivity: Vent Connector - Masonry Chimney					
Properties	AFUE	82%	83%	84%	85%
	Chimney Material	Masonry	Masonry	Masonry	Masonry
	Connector Material	Single Wall	Single Wall	Single Wall	Single Wall
Connector Wet Time, min	*Boiler 1 Wet Time [min]*	NA	NA	NA	NA
	Boiler 2 Wet Time [min]	4.7	5.7	7.7	*
	Boiler 1 Wet Time [min]	5.0	6.0	8.0	*
	Connector Material	Type B	Type B	Type B	Type B
Connector Wet Time, min	*Boiler 1 Wet Time [min]*	NA	NA	NA	NA
	Boiler 2 Wet Time [min]	2.3	2.7	3.3	4.7
	Boiler 1 Wet Time [min]	2.7	3.0	3.7	5.0

Discussion

The assumptions used in the development of the venting tables for Category I appliances in the NFGC are that the vents would dry out during each appliance cycle to avoid pooling and carry-over of acidic condensate. For masonry chimneys, a criterion was added that the chimney would need to dry out after 12 hours of cycling. Although not explicitly stated in the NFGC, 83% steady-state efficiency was used as the Category I limit for the code. Appliances operating outside of the wet time limit were Category II appliances and would require their own instructions on vent sizing and (acid-resistant) materials.

The results show that there are many instances when boilers exceed the 3.8 minute connector wet time used in the code, the masonry chimney 12 hour dryout rule also used in the code, or the 9.6 minute boiler cycle time from the ASHRAE 103 standard and the DOE test procedure. In this analysis, every 85% AFUE boiler case and many of the 83 - 84% boilers cases exceeded one or more of these wet time limits.

Exceeding the wet time limit means that the boilers at the 84% AFUE and 85% AFUE efficiency levels in this study under the conditions investigated should not be connected to venting systems used for Category I appliances but would require their own venting instructions specifying vents and connectors with water-tight joints, corrosion-resistant materials and condensate drains.

These results clearly indicate that under certain conditions boilers with AFUE ratings of 84% or 85% installed in existing metal vents and masonry chimneys will be presented with a greater risk of corrosion-based failure (for metal vents and vent connectors) or freeze thaw damage and other durability-related failures (for masonry chimneys). The issue of common venting with draft-hood equipped water heaters needs to be investigated.

Conclusions and Implications

The objective of this project was to determine the effect of increasing boiler efficiency levels above the current NAECA minimum on the performance of the vent.

The results show that there are many scenarios where boilers above 82% AFUE (82.3% steady state efficiency) will create conditions that will cause excessive corrosion in vent connectors and deterioration of the vertical section of masonry chimneys, according to the VENT-II analysis. If chimney liners are installed, the scenarios show excessive corrosion in the Type B vent connector at 85% AFUE and above.

Implications to the manufacturers are that non-condensing boilers designed to operate above the 82% AFUE limit will require additional installation instructions that may either restrict the characteristics of Category I venting systems that are connected to the unit or specify alternative venting systems which have water tight joints, are made of corrosion-resistant materials, and include condensate drains.

References

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Detty, DW, Mawlakar, S.R, and McKeown, SW. August 1998. *Topical Report: VENT-II Users Guide, Version 5.0*. Battelle, Columbus Ohio, for Gas Research Institute

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List of Acronyms

Acronym	Description
AGA	**American Gas Association**
AHRI	**Air Conditioning, Heating, and Refrigeration Institute**
DOE	**Department of Energy**
GTI	**Gas Technology Institute**
GRI	**Gas Research Institute**
HVAC	**Heating, Ventilation, and Air Conditioning**
NFGC	**National Fuel Gas Code**

Appendix A – List of Assumptions and Specifications

Boiler Capacity

Boiler #	Capacity
1	71 kBtu/h
2	286 kBtu/h
3	283 kBtu/h

Damper Specifications

Settings used for all boiler simulations.

Opening Time	15 sec
Closing Time	15 sec
Ratio of Open Damper Area to Vent Area	0.86
Ratio of Closed Damper Area to Vent Area	0.04
Angle b/t Open and Closed Damper	90°

Vent Specifications

Configuration

Used for all boiler simulations.

Vent Height	16 ft.
Vent Lateral – Type B Vent Lateral – Masonry	10 ft. 3 ft.
Connector Rise	1 ft.

Ambient Temperatures

Used for all boiler simulations

Connector	60 °F
Lateral	60 °F
Common – Lowest 10 feet	60 °F
Common – Next 2 feet	60 °F
Common – Last 3 feet	42 °F

Vent Requirements and Assumptions

NFGC Vent Connector Requirements

Connector Type	Minimum Thickness Requirement
Single Wall Galvanized Steel	0.018 in.
Type B	None; VENT-II default thickness used in place

Source: 2012 NFGC Section 12.11.2.3 Material requirements for category 1 appliance vent connectors

VENT II Type B Section Default Thickness and Materials

Connector Type	Thickness Requirement	Total Thickness	Outer Layer Thickness	Outer Layer Material	Inner Layer Thickness	Inner Layer Material	Air Gap Thickness
Type B	No thickness requirement	0.25 in.	0.019 in.	Galvanized Steel	0.012	Aluminum	~0.22

Source: VENT-II User Manual

VENT II Masonry Chimney Defaults

M1- Masonry	
Outer Layer material	Brick
Outer Layer Thickness	4 in.
Inner Layer Material	Clay Tile
Inner Layer Thickness	0.75 in.
Gap Material	Air

Source: VENT-II User Manual

Vent Sizing

Type B Connector / Type B Common

NFGC Vent Sizing

Boiler #	Connector Diameter	Common Vent Diameter	NFGC Nat Max[1]
1	4 in.	4 in.	82 kBTU/h to 89 kBTU/h
2	7 in.	7 in.	288 kBTU/h to 321 kBTU/h
3	7 in.	7 in.	288 kBTU/h to 321 kBTU/h

Source: NFGC Table 13.1(a) Type B Double Wall Gas vent for / Single Appliance / Connected Directly

VENT II

Connector Thickness	0.25
Vent Thickness	0.25

Source: VENT-II Type B default total thickness (both walls + air gap)

Single-Wall Connector / Type B Common

NFGC Vent Sizing

Boiler #	Connector Diameter	Common Vent Diameter	NFGC Nat Max[1]
1	4 in.	4 in.	79 kBTU/h to 86 kBTU/h
2	8 in.	8 in.	381 kBTU/h to 437 kBTU/h
3	8 in.	8 in.	381 kBTU/h to 437 kBTU/h

Source: NFGC Table 13.2 (b) Type B Double Wall Gas Vent / Single Appliance / Single Wall Metal Connector

VENT II

Connector Thickness	0.018 in.
Vent Thickness	0.25 in.

1 Range provided for 15 ft. to 20 ft. total height with 10 ft. lateral. Interpolation is allowed for NFGC tables.

Type B Connector / Masonry Chimney

NFGC Vent Sizing

Boiler #	Connector Diameter [in]	Minimum Internal Area of Chimney [in^2]	VENT II Common Vent Circular Liner Diameter [in]	NFGC Nat Max[1]
1	5 in.	28 in^2	6 in.	97 kBTU/h to 107 kBTU/h
2	8 in.	63 in^2	9 in.	296 kBTU/h to 332 kBTU/h
3	8 in.	63 in^2	9 in.	296 kBTU/h to 332 kBTU/h

Source: NFGC Table 13.2 (c) Masonry Chimney / Single Appliance / Type B Connector

VENT II

Connector Thickness	0.25 in.
Total Thickness	5.5 in.
Outer Wall [Brick]	4 in.
Air Space	0.75 in.
Inner	0.75 in.

Single-Wall Connector / Masonry Chimney

NFGC Vent Sizing

Boiler #	Connector Diameter [in]	Minimum Internal Area of Chimney [in^2]	VENT II Common Vent Circular Liner Diameter [in]	NFGC Nat Max[1]
1	5 in.	28 in^2	6 in.	96 kBTU/h to 105 kBTU/h
2	8 in.	63 in^2	9 in.	294 kBTU/h to 330 kBTU/h
3	8 in.	63 in^2	9 in.	294 kBTU/h to 330 kBTU/h

Source: NFGC Table 13.2 (d) Masonry Chimney / Single Appliance / Single-wall Metal Connector

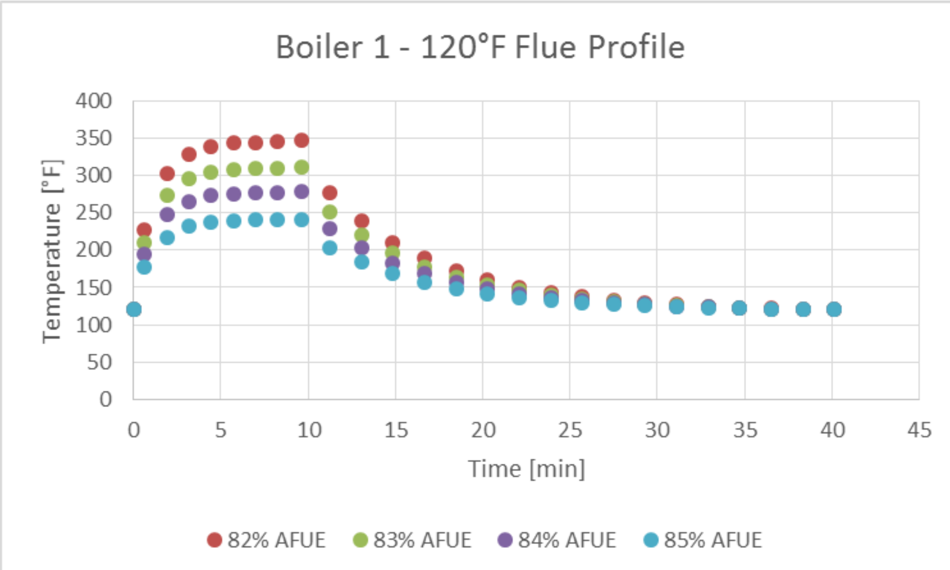
VENT II

Connector Thickness	0.018 in.
Total Thickness	5.5 in.
Outer Wall [Brick]	4 in.

Air Space	0.75 in.
Inner	0.75 in.

Boiler Profiles

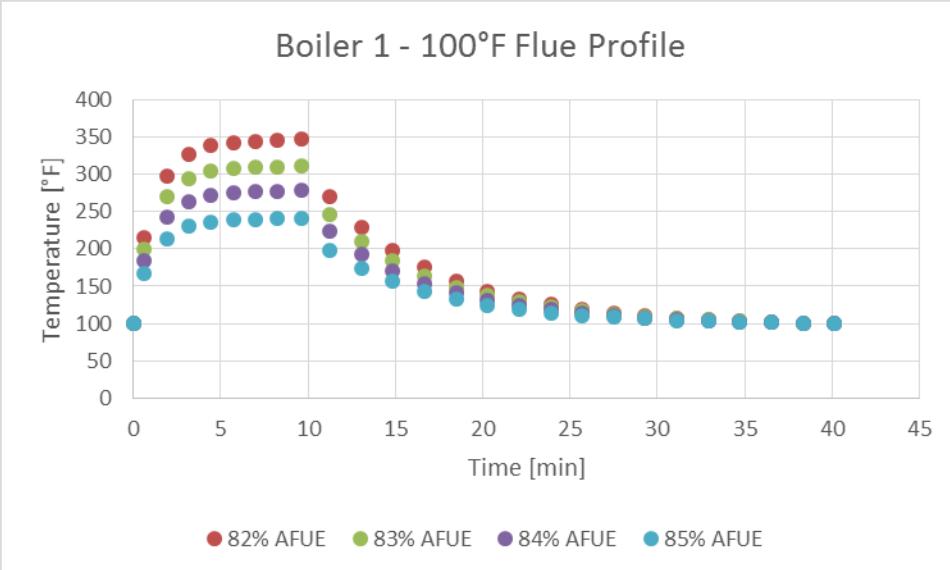
Boiler 1 – 120 °F Minimum Flue Outlet Temperature



Boiler 1 Flue Profile – Minimum Flue Temperature of 120 °F				
Time [min]	82% AFUE	83% AFUE	84% AFUE	85% AFUE
0.00	120.00	120.00	120.00	120.00
0.64	226.56	209.74	194.31	177.02
1.91	302.66	273.82	247.38	217.74
3.18	328.95	295.96	265.71	231.81
4.45	339.49	304.84	273.07	237.45
5.72	343.55	308.25	275.90	239.62
6.99	344.97	309.45	276.89	240.38
8.25	346.02	310.33	277.62	240.94
9.60	348.00	312.00	279.00	242.00
11.26	276.88	252.11	229.40	203.94
13.07	238.94	220.16	202.95	183.65
14.87	210.59	196.29	183.18	168.48
16.67	188.94	178.05	168.07	156.89
18.48	172.58	164.28	156.67	148.13
20.28	160.22	153.87	148.05	141.52
22.09	150.80	145.94	141.48	136.48
23.89	143.56	139.84	136.43	132.61
25.70	137.99	135.15	132.55	129.63
27.50	133.51	131.37	129.42	127.23
29.31	129.93	128.36	126.92	125.31

Boiler 1 Flue Profile – Minimum Flue Temperature of 120 °F				
Time [min]	82% AFUE	83% AFUE	84% AFUE	85% AFUE
31.11	127.08	125.96	124.94	123.79
32.92	124.81	124.05	123.35	122.57
34.72	123.08	122.60	122.15	121.65
36.53	121.72	121.45	121.20	120.92
38.33	120.74	120.62	120.51	120.39
40.13	120.00	120.00	120.00	120.00

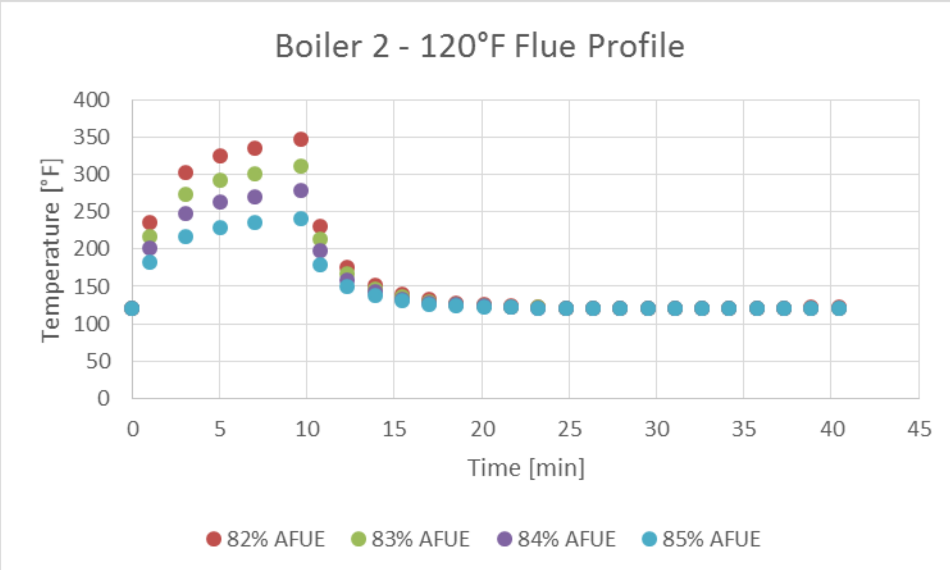
Boiler 1 – 100 °F Minimum Flue Outlet Temperature



Boiler 1 Flue Profile – Minimum Flue Temperature of 100 °F				
Time [min]	82% AFUE	83% AFUE	84% AFUE	85% AFUE
0.00	100.00	100.00	100.00	100.00
0.64	215.91	199.09	183.66	166.37
1.91	298.69	269.85	243.41	213.76
3.18	327.28	294.29	264.04	230.13
4.45	338.75	304.09	272.32	236.70
5.72	343.16	307.86	275.51	239.23
6.99	344.71	309.19	276.62	240.12
8.25	345.85	310.16	277.45	240.77
9.60	348.00	312.00	279.00	242.00
11.26	270.64	245.87	223.16	197.71
13.07	229.38	210.60	193.38	174.08
14.87	198.54	184.24	171.12	156.42
16.67	174.98	164.10	154.12	142.93
18.48	157.19	148.89	141.28	132.75

Boiler 1 Flue Profile – Minimum Flue Temperature of 100 °F				
Time [min]	82% AFUE	83% AFUE	84% AFUE	85% AFUE
20.28	143.75	137.40	131.58	125.05
22.09	133.50	128.64	124.18	119.18
23.89	125.63	121.91	118.50	114.68
25.70	119.57	116.73	114.13	111.21
27.50	114.69	112.56	110.60	108.41
29.31	110.80	109.23	107.80	106.18
31.11	107.70	106.58	105.56	104.41
32.92	105.23	104.47	103.77	102.99
34.72	103.35	102.87	102.42	101.92
36.53	101.87	101.60	101.35	101.07
38.33	100.80	100.68	100.58	100.46
40.13	100.00	100.00	100.00	100.00

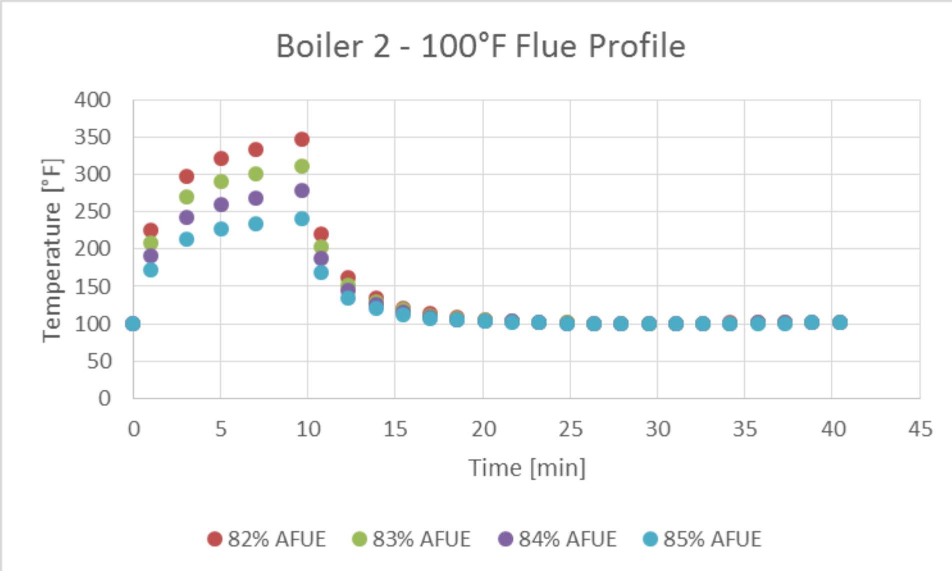
Boiler 2 – 120 °F Minimum Flue Outlet Temperature



Boiler 2 Flue Profile – Minimum Flue Temperature of 120 °F				
Time [min]	82% AFUE	83% AFUE	84% AFUE	85% AFUE
0.00	120.00	120.00	120.00	120.00
1.02	236.05	217.72	200.93	182.10
3.03	302.69	273.85	247.40	217.76
5.04	324.67	292.36	262.73	229.52
7.05	335.91	301.82	270.57	235.53
9.67	348.00	312.00	279.00	242.00
10.76	231.05	213.52	197.44	179.42
12.32	176.36	167.46	159.31	150.16
13.88	152.47	147.34	142.64	137.38
15.44	139.59	136.49	133.66	130.48
17.00	132.07	130.16	128.41	126.46
18.56	127.80	126.57	125.44	124.17
20.12	125.41	124.56	123.77	122.90
21.68	123.64	123.07	122.54	121.95
23.24	122.12	121.78	121.48	121.13

Boiler 2 Flue Profile – Minimum Flue Temperature of 120 °F				
Time [min]	82% AFUE	83% AFUE	84% AFUE	85% AFUE
24.81	121.11	120.93	120.77	120.59
26.37	120.69	120.58	120.48	120.37
27.93	120.41	120.34	120.28	120.22
29.49	120.34	120.29	120.24	120.18
31.05	120.08	120.07	120.06	120.04
32.61	120.00	120.00	120.00	120.00
34.17	120.95	120.80	120.66	120.51
35.73	121.32	121.11	120.92	120.71
37.29	121.50	121.26	121.04	120.80
38.85	121.71	121.44	121.19	120.91
40.42	121.66	121.40	121.16	120.89

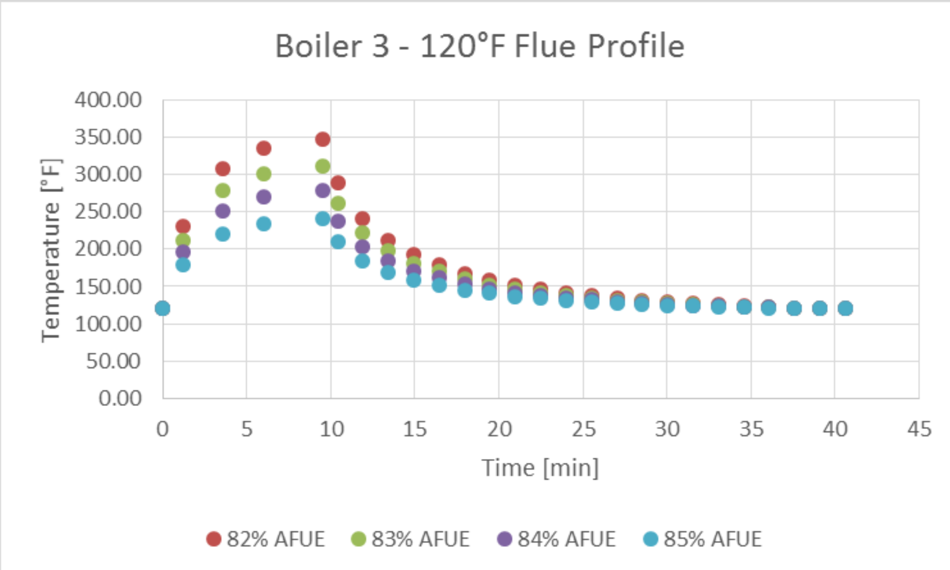
Boiler 2 – 100 °F Minimum Flue Outlet Temperature



Boiler 2 Flue Profile – Minimum Flue Temperature of 100 °F				
Time [min]	82% AFUE	83% AFUE	84% AFUE	85% AFUE
0.00	100.00	100.00	100.00	100.00
1.02	226.23	207.90	191.11	172.28
3.03	298.72	269.87	243.43	213.78
5.04	322.63	290.31	260.69	227.47
7.05	334.85	300.76	269.51	234.47
9.67	348.00	312.00	279.00	242.00
10.76	220.79	203.26	187.18	169.16
12.32	161.31	152.41	144.25	135.10
13.88	135.32	130.19	125.49	120.22
15.44	121.31	118.21	115.38	112.20
17.00	113.12	111.22	109.47	107.51
18.56	108.49	107.25	106.13	104.86
20.12	105.89	105.03	104.25	103.37
21.68	103.96	103.39	102.86	102.27
23.24	102.30	101.97	101.66	101.32

Boiler 2 Flue Profile – Minimum Flue Temperature of 100 °F				
Time [min]	82% AFUE	83% AFUE	84% AFUE	85% AFUE
24.81	101.21	101.03	100.87	100.69
26.37	100.75	100.64	100.54	100.43
27.93	100.44	100.38	100.32	100.25
29.49	100.37	100.32	100.27	100.21
31.05	100.09	100.07	100.06	100.05
32.61	100.00	100.00	100.00	100.00
34.17	101.03	100.88	100.74	100.59
35.73	101.44	101.23	101.04	100.82
37.29	101.63	101.39	101.18	100.93
38.85	101.86	101.59	101.34	101.06
40.42	101.80	101.54	101.30	101.03

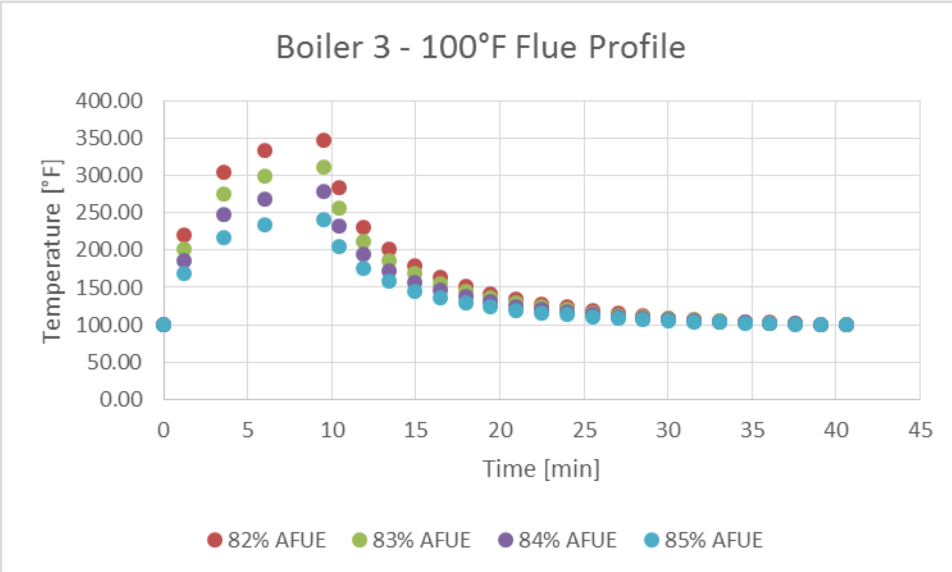
Boiler 3 – 120 °F Minimum Flue Outlet Temperature



Boiler 3 Flue Profile – Minimum Flue Temperature of 120 °F				
Time [min]	82% AFUE	83% AFUE	84% AFUE	85% AFUE
0.00	120.00	120.00	120.00	120.00
1.20	230.15	212.75	196.81	178.94
3.61	308.09	278.39	251.17	220.64
6.01	335.03	301.08	269.95	235.06
9.52	348.00	312.00	279.00	242.00
10.40	288.64	262.02	237.61	210.24
11.91	240.57	221.53	204.08	184.52
13.42	212.77	198.12	184.69	169.64
14.93	193.32	181.74	171.13	159.23
16.44	179.31	169.95	161.36	151.74
17.96	167.96	160.39	153.44	145.66
19.47	158.56	152.47	146.89	140.63
20.98	151.08	146.17	141.68	136.63
22.49	145.92	141.83	138.08	133.87
24.00	141.73	138.30	135.15	131.63

Boiler 3 Flue Profile – Minimum Flue Temperature of 120 °F				
Time [min]	82% AFUE	83% AFUE	84% AFUE	85% AFUE
25.51	137.48	134.72	132.19	129.35
27.02	133.79	131.61	129.61	127.38
28.53	130.75	129.06	127.50	125.75
30.04	128.66	127.30	126.04	124.64
31.55	126.80	125.72	124.74	123.64
33.07	125.15	124.34	123.59	122.76
34.58	123.78	123.18	122.63	122.02
36.09	122.54	122.14	121.77	121.36
37.60	121.37	121.15	120.95	120.73
39.11	120.65	120.55	120.45	120.35
40.62	120.00	120.00	120.00	120.00

Boiler 3 – 100 °F Minimum Flue Outlet Temperature



Boiler 3 Flue Profile – Minimum Flue Temperature of 100 °F				
Time [min]	82% AFUE	83% AFUE	84% AFUE	85% AFUE
0.00	100.00	100.00	100.00	100.00
1.20	219.81	202.42	186.47	168.60
3.61	304.59	274.89	247.66	217.14
6.01	333.89	299.94	268.81	233.92
9.52	348.00	312.00	279.00	242.00
10.40	283.44	256.81	232.40	205.03
11.91	231.15	212.11	194.66	175.09
13.42	200.90	186.26	172.83	157.78
14.93	179.75	168.17	157.56	145.66
16.44	164.51	155.15	146.56	136.94
17.96	152.17	144.59	137.65	129.87
19.47	141.94	135.85	130.27	124.02
20.98	133.81	128.90	124.40	119.36
22.49	128.19	124.10	120.35	116.14
24.00	123.63	120.20	117.06	113.53

Boiler 3 Flue Profile – Minimum Flue Temperature of 100 °F				
Time [min]	82% AFUE	83% AFUE	84% AFUE	85% AFUE
25.51	119.01	116.25	113.72	110.89
27.02	114.99	112.82	110.82	108.59
28.53	111.70	110.00	108.44	106.70
30.04	109.42	108.06	106.80	105.40
31.55	107.39	106.32	105.34	104.23
33.07	105.60	104.79	104.04	103.21
34.58	104.11	103.51	102.97	102.35
36.09	102.77	102.36	102.00	101.58
37.60	101.49	101.27	101.07	100.85
39.11	100.71	100.60	100.51	100.40
40.62	100.00	100.00	100.00	100.00