AIR-CONDITIONING, HEATING, & REFRIGERATION INSTITUTE
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July 10, 2015

Ms. Brenda Edwards
U.S. Department of Energy
Building Technologies Program, EE-2B
1000 Independence Avenue, S.W.
Washington, D.C. 20585-0121

Re: NOPR Test Procedures for Residential Furnaces and Boilers
Docket No. EERE-2012-BT-TP-0024

Dear Ms. Edwards:

The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) is the trade association representing manufacturers of air conditioning, space heating, water heating and commercial refrigeration equipment. AHRI's 315 member companies include all the major manufacturers of residential furnaces and boilers (gas and oil-fired) doing business in the U.S. We submit the following comments in response to the March 11, 2015 Federal Register Notice of Proposed Rulemaking (NOPR) to revise the DOE efficiency test procedure for residential furnaces and boilers.

Legal and Practical Requirements Mandate that DOE Finalize the Proposed Test Procedure Before Promulgating an Amended Energy Conservation Standard.

DOE published the NOPR on March 11, 2015. On March, 12, 2015, the very next day, DOE published a proposal to revise energy efficiency standards for residential furnaces. Three weeks later, on March 31, 2015 DOE published a proposal to revise the residential boiler efficiency standards. If DOE proceeds to finalize the amendments in this proposed test procedure, AHRI requests that DOE delay any further work on the rulemaking to amend efficiency standards for residential furnaces and for residential boilers until after that finalization. Additionally, only then should DOE re-open the docket for further comment on the proposed revised efficiency standards. In the alternative, AHRI requests that DOE suspend this rulemaking and continue to work only on the rulemakings for revised efficiency standards for residential furnaces and boilers.

AHRI has both legal and practical concerns about the tandem proposal of test procedure and standard revisions for the following reasons: (1) the proposed, non-final status of the test procedure inhibits stakeholders' fair evaluation of the standard; (2) DOE has failed to abide by its codified procedures by publishing the NOPR within weeks of the proposed efficiency standards; and (3) DOE either (a) has already missed its statutory deadline for the finalization of the amended test procedure by over six months; or (b) misinterpreted its statutory deadline, and therefore has an additional five years to finalize an amended test procedure, providing ample time to complete the current rulemakings on revised efficiency standards for residential furnaces and boilers.

The importance of having a known efficiency test procedure is well recognized. Manufacturers must test equipment to determine how its products are affected by any proposed efficiency standard. When the test procedure used to assess a standard is in flux, it places the manufacturer in the position of spending time and resources to collect potentially useless data and undermines its ability to provide relevant input on the proposed efficiency standards because the method by which that standard will be applied and the data

collected may change. The reverse is also true—when a test procedure is in the process of being changed a manufacturer has no way of determining whether the test procedure will affect its ability to comply with a proposed revised standard. Therefore the manufacturer cannot adequately comment on test procedure proposals. The dilemma is aggravated when manufacturers advocate for a change to the proposed test procedure during the comment period, as AHRI does here. DOE is required to give stakeholders the opportunity to submit meaningful comments, and the joint proposal of test procedures and standards diminishes that opportunity. *See* 42 U.S.C. §§ 6295(p)(2), 6306(a).

Because DOE is well aware of the detriment that a tandem proposal for test procedure and standard presents to stakeholders, it codified a procedure designed to avoid this disadvantage. 10 C.F.R. § 430 Subpart B, Appendix A (7)(b). DOE declared that it would finalize amended test procedures before introducing applicable amended standards. *Id.* In this instance, DOE has failed to abide by its own codified procedures. The Administrative Procedure Act (APA) requires agencies to abide by their policies and procedures, especially where those rules have a substantive effect. *U.S. v. Heffner*, 420 F.2d 809 (4th Cir. 1969); *Adams v. Bell*, 711 F.2d 161, 183 (D.C. Cir. 1983). The non-final test procedure has the substantive effect of increasing costs to stakeholders and diminishing their ability to comment on the efficiency standards.

Under EPCA, one interpretation is that DOE was required to finalize this test procedure on December 19, 2014, four months before it was proposed. *See* 80 Fed. Reg. 17,235, 42 U.S.C. § 6293(b)(1)(A). Had DOE met this statutory deadline, the amended test procedure would now be final, and stakeholders would have a genuine opportunity to assess the applicable revised efficiency standards currently being proposed. By failing to meet its statutory requirements, DOE has compromised stakeholders' rights to equitably comment on proposed rules. There is another interpretation that has not been considered and which we believe is more correct. As noted by DOE, the current test procedure was published on July 10, 2013. *See* 80 Fed. Reg. 12,877 citing 78 Fed. Reg. 41,265 (July 10, 2013). At that time amendments were added to provide a more accurate AFUE measurement for certain types of residential furnaces and boilers. This amended efficiency test procedure was processed through the normal course of notice and comment procedures, and therefore satisfies the statutory requirements of 42 U.S.C. § 6293(b)(1)(A). The action on July 10, 2013 was clearly within 7 years of the Energy Policy Act, enacted in December 2007. Accordingly, the start date for the obligation to review efficiency test procedures at least once every 7 years has been reset to July 10, 2013. DOE has approximately five more years to review and amend, as needed, these efficiency test procedures, which is ample time to manage its rulemaking activities such that proposed revisions to efficiency standards and test procedures are not considered concurrently.

In addition to our concern regarding the simultaneous development of rulemakings on test procedures and efficiency standards for residential furnaces and boilers, we have a fundamental concern that the proposed revised efficiency test procedure may actually result in a different AFUE rating for many models. As DOE is aware, test procedure amendments may not substantively affect efficiency standards. EPCA states: "In the case of any amended test procedure…the Secretary shall determine, in the rulemaking carried out with respect to prescribing such procedure, to what extent, if any, the proposed test procedure would alter the measured energy efficiency…of any covered product as determined under the existing test procedure." 42 U.S.C. § 6293(e)(1). AHRI requests that the DOE conduct tests of a representative sample of furnaces and boilers that minimally comply with the existing standard, as required by EPCA, taking into account important changes to the test procedure, in order to correspondingly reset the proposed minimum efficiency standards as mandated by 42 U.S.C. § 6293(e)(2).

The testing that DOE has conducted on 14 two-stage or modulating models does not adequately cover the range of products covered by this test procedure and is insufficient to support any conclusion regarding the effect of the proposed revised test procedure on the AFUE ratings of all models. As an example of this inadequacy we note that DOE tested only 5 gas boilers and no oil-fired boilers. Of the 5 gas boilers tested 3 were condensing gas boilers. But all 3 had AFUE ratings at the low end of the range of AFUE ratings for available condensing models. Additionally, no "Testing report" as cited in footnote 3 on page 12878 of the NOPR Federal Register notice, was available in the docket. Thus we had no opportunity to review the details of these tests to assess the degree to which they reflected the range of models currently available.

We have identified several changes in the proposed revised test procedures which we believe do change the resulting AFUE measurement for some models covered by the test procedure. One particularly significant change is the proposed revisions which add greater detail on adjusting gas and oil burners for the test. The propose change requires a gas burner to be adjusted to achieve either an excess air ratio, flue O_2 percentage or flue CO_2 percentage within the middle 30th percentile of the acceptable range specified in the I & O manual. In the absence of such a specification, the burner shall be adjusted to provide a dry flue gas O_2 measurement between 6.9% to 7.1% or the lowest dry flue gas O_2 percentage that produces a stable flame and an air free flue gas CO ratio below 400 ppm. Also, it requires an oil burner to be adjusted to give a CO_2 reading within the middle 30th percentile of the specified range in the I&O manual. In the absence of such a specification, the burner shall be adjusted to achieve a dry flue gas CO_2 percentage between 10.0% and 10.4% or a dry flue gas CO2 percentage that results in flue gas smoke that does not exceed No. 1 smoke. The specification of "the middle 30th percentile of the acceptable range" is confusing. The 30th percentile is a single value so we do not understand what is meant by the "middle 30th percentile". We asked for the intended meaning of this phrase at the March 26, 2015 public meeting but received no clarifying response at that time.

Notwithstanding this confusion, it is clear that these proposed burner adjustments are more restrictive than both the current test procedure and the specifications found in ASHRAE Standard 103-2007. For many gas furnaces and boilers which use atmospheric burners, these adjustments cannot be made. For all oil fired furnaces and boilers, this change may be significant and will change the current AFUE ratings of many models. The current test procedure for residential furnaces and boilers specifies that the burners for oil-fired models be adjusted to give a CO_2 reading recommended by the manufacturer and which does not produce smoke in the flue exceeding No. 1 smoke. Accordingly, units are being tested at CO_2 levels of 13% to 14%. If the manufacturer specifies a range, this test value is always at the upper end of the range. In some cases manufacturers do not specify a range. In either case the proposed change will result in the CO_2 reading being appreciably lower than 13% which will result in a lower AFUE measurement. The amount of change may be different for oil furnaces compared to that of oil boilers because of the difference in burner operation when firing against an air-backed heat exchange as compared to firing against a water-backed heat exchanger, but the change in AFUE does apply to both products.

Attached is a report on the testing of 3 residential boilers which we had conducted at Intertek Testing Laboratories to evaluate the effects of DOE's proposed revised efficiency test procedures. Specifically, the testing project evaluated the impact of changes being proposed to the burner setup instructions (CO_2/O_2) and the on/off times for the cyclical condensate test. This additional testing was conducted on residential boilers which were selected for annual testing as part of the AHRI Residential Boiler efficiency certification program. The results of this testing show that the proposed revised burner setup

requirements do change AFUE ratings. The data indicates a .3% change in AFUE for each 1% difference in the CO_2 values, e.g. an AFUE of 92% when tested with a CO_2 of 13% will drop to 91.1 % when tested with a CO_2 of 10%. Some of our members have conducted their own tests and have confirmed that the revised burner setup requirements do change the AFUE. In the case of one of our oil furnace manufacturer members, they tested a model for which the I&O manual does not provide any specified acceptable CO_2 range. The models current AFUE rating is based on testing with a CO_2 setting a little above 13%. When this model was tested per the proposed test procedure the CO_2 setting was a little above 10% and the AFUE was a full 2 percentage points lower. DOE's own test data showed a difference in AFUE ratings resulting from the proposed revised burner setup requirements but concluded that the changes were "de minimis." That conclusion is refuted by the information we and our members have provided and underscores the need for DOE to conduct more testing to correctly assess the effect of the revisions being proposed.

The burner adjustment specifications in the DOE furnace and boiler test procedure have been unchanged since the procedures were first established. The NOPR did not provide any information to explain why this change is being proposed and DOE did not respond to our subsequent request for that information. DOE has not conducted adequate testing to ascertain the effect of the change in burner adjustments. In the absence of such information and the fact that different AFUE measurements will result from this proposed change for many current models of furnaces and boilers, we recommend that DOE not finalize these proposed changes on adjusting gas and oil burners.

If there was some underlying issue that DOE wanted to address by these changes, we suggest that DOE allow the manufacturers to provide additional information regarding the setup of the unit for efficiency testing, as is currently done for certification reports on commercial and industrial equipment.

The proposed change to require only the reduced fire test for certain parts of the testing of two-stage/modulating products where the balance point temperature (Tc) in 5°F or less provides some testing burden relief only for furnaces. As noted at the March 26, 2015 public meeting, most boiler models will not satisfy the balance point criteria to allow the use of this option because the ratio of $Q_{OUT,R}$ to Q_{OUT} for these models is on the order of 1 to 10. In comparison that ratio for most furnace models is on the order of 4 to 5.

The combined effect of the change to use calculated values for t_{on} and t_{off} and conduct the condensate cycle test at those calculated t_{on} and t_{off} values, at a minimum, will require retesting for any step-modulating models at the reduced input rate and for many two stage models at both the maximum and reduced input rates. The trend indicated from the 7 condensing units (4 gas furnaces, 3 gas boilers) is that a slightly lower AFUE measurement occurs with these changes. For two of the furnaces, the AFUE was about 1 percentage point less. That is a significant change which, if held true for testing of additional units of that model, would require the model to be rerated to a lower AFUE.

As discussed above, DOE is prohibited from altering an efficiency standard via a test procedure. DOE attempts to dismiss the changes implicated by the NOPR, expressing that such effects are "de minimis." In fact, such alterations are not "de minimis," and DOE has no authority to overlook resulting changes in AFUE, regardless of how DOE characterizes the resulting effects. Section 6293(e)(2) specifies that "if … the amended test procedure ***will alter*** the measured efficiency…, the Secretary ***shall amend*** the applicable energy conservation standard…." Nowhere in EPCA is DOE permitted to ignore alterations in measured efficiency caused by an amended test procedure. By reading a "de minimis" exception into EPCA, DOE

is unlawfully expanding the scope of its authority. DOE is required to amend the applicable standard if there is a change in AFUE. To ignore this requirement, would be to defy a limitation on its statutory authority. "Such an act is necessarily arbitrary and capricious." *United Mine Workers v. Dole*, 870 F.2d 662, 673 (D.C. Cir. 1989).

We support the proposed change to allow the measurement of condensate during the establishment of steady-state conditions. However, this change should be clearly identified as an option to the current procedure which specifies that condensate is measured after steady state conditions are established during a 30 minute period. DOE's limited testing on boiler indicated that the condensate measured by either method was essentially the same. To avoid an unintended consequence of causing manufacturers to retest existing models to remeasure the amount of condensate, the procedure must be included as an optional alternate way to measure condensate.

The NOPR identifies several issues on which DOE seeks comment. Our comments are provided below.

1. ASHRAE 103 Update from Version 1993 to 2007
   DOE requests comment from stakeholders on the proposed changes to the DOE test procedure resulting from incorporating the 2007 version of ASHRAE 103 with some limited modifications.

   This has been addressed in our general comments.

2. Measurement of Condensate Under Steady-State Conditions
   DOE requests comment from stakeholders on the proposed changes to allow for the measurement of condensate during the establishment of steady-state conditions (ASHRAE 103-2007, section 9.1).

   This has been addressed in our general comments.

3. Additional Auxiliary Electrical Consumption
   In this NOPR, DOE proposes changes to the test procedure by updating the incorporation by reference of ASHRAE 103 to the 2007 version and by incorporating testing of auxiliary electricity components. DOE requests comment from stakeholders on these proposed changes.

   The proposed changes over complicate this issue. For the typical gas burner, the electrical energy that is consumed during burner operation involves the electricity use by the ignition system and gas control. This was acknowledged to some degree by including the reference to the energy use of the energized electric ignition device in the definition of PE. The burner will not operate unless both the ignition system and gas control (e.g. automatic valves) are energized. The definition of PE should be clarified to include all electrical energy consumption that relates to the functions of igniting and operating the burner during its on cycle.

   It should be noted that this will change the measurement of E_{AE}. Information provided by DOE at the March 26, 2015 public meeting indicated that the change could be an increase of 7 to 11%. Information from our members suggest an even larger potential difference; from – 8.5% to +13%. This is another example that the proposed test procedure is not neutral relative to the measurements it provides and that there is a test burden which DOE has not recognized.

4. Installation and Operation Manual Reference

   DOE requests comment on its proposal to clarify the test procedure language to explicitly state that testing recommendations should be drawn from each product's approved I&O manual, and to

provide a specific combustion airflow ratio, reduced fuel input rate, and draft settings when the manufacturer does not provide recommended values in the I&O manual provided with the unit.

The proposals in the NOPR to address this issue are inappropriate and will alter current AFUE ratings. The current provisions of the test procedure are adequate for the purposes of measuring the efficiency of the furnace or boiler. If DOE is concerned about the situation where the manufacturer does not provide any recommended settings in the I&O manual, then DOE should allow the manufacturer to provide additional information on setting up the unit for testing as part of the certification report, as is done for commercial and industrial equipment. One example, where this will be needed is information on disabling the automatic means so that the unit can be operated under the conditions specified by the test.

5. Automatic Means for Adjusting Water Temperature Testing

DOE seeks stakeholder comment on any additional methods for inferring building heat load to ensure that DOE's proposed test method validates the functionality of all strategies currently available in the market used to provide an automatic means for adjusting water temperature.

We recognize that this proposed method to check the functioning of the automatic means for adjusting water temperature is intended to be used only when DOE wants to validate that this means is present on the boiler and functioning and that it is not required for certification of the model. However, in order to address the variety of ways in which this feature is provided on boilers, the proposed test must be specified in broad terms. Furthermore, the criterion to confirm the functioning of the means is a non-qualitative requirement that either there is a delay in the burner coming on or there is a change in the supply water temperature, as applicable. Thus the test becomes so vague to the point of being meaningless. We recommend that DOE not finalize this proposed procedure and not pursue further the concept of adding a test to verify the functioning of the automatic means.

6. Test Method for Indicating the Absence of Flow through the Heat Exchanger

DOE is interested in whether, in addition to the proposed smoke stick test, other options exist for measuring or indicating the absence of flow through the heat exchanger.

No comment.

7. AFUE Reporting Precision

DOE's existing furnaces and boilers test procedure specifies that the AFUE rating be rounded to the nearest whole percentage point. DOE requests comment on its proposal to update the existing requirement for residential furnaces and boilers to report AFUE to the nearest tenth of a percentage point.

We support this proposal and note that it reflects the historical practice of how AFUE ratings have been reported and displayed since the test procedure was first established.

8. Duct Work for Units That Are Installed Without a Return Duct

DOE requests comments on the proposal to add a provision in the test procedure clarifying that the return (inlet) duct is not required during testing for units which, according to the manufacturer's I&O manual, are intended to be installed without a return duct.

No comment.

9. Testing Requirements for Multiposition Configurations

DOE requests comment on its proposal to allow testing of units configured for multiple position installations to use the blower access door as an option instead of one of the inlet openings.

No comment.

10. Room Ambient Air Temperature and Humidity Ranges

DOE requests comment from stakeholders on DOE's preliminary determination not to propose changes to the test procedure regarding room ambient temperature and humidity, neither in the form of a mathematical correction methodology nor by limiting the existing ambient condition ranges.

No comment.

11. Oversize Factor Value

DOE did not receive data supporting a change to the existing oversize factor of 0.7. DOE proposes to maintain the existing oversize factor and seeks comment on the appropriateness of this strategy.

No comment.

The information we have provided on comparative tests using the current and proposed test procedures indicates that the proposed test procedure will result in different AFUE measurements. As we have noted, if DOE proceeds with these test changes DOE is obligated to conduct tests to determine the effect of the proposed test procedures and convert the current minimum AFUE standards for residential furnaces and boilers, gas and oil, accordingly. We have further noted DOE's deviation from its own procedure which specifies that test procedure revisions should be finalized before revised efficiency standards are proposed for products covered by those test procedures. It is clear that DOE's intent in this NOPR was to update the test procedure to use a more current edition of ASHRAE Standard 103 and include several other minor changes that would have no effect on the resulting AFUE measurement. If the NOPR had met that intent, it would have been finalized relatively quickly and without controversy. Such is not the case. The finalization of this proposed test procedure will require considerably more time and continue to complicate the rulemakings to revise the minimum efficiency standards for residential boilers and gas furnaces. It will also impose a significant testing burden on manufacturers that will be for the most part an unnecessary waste of time and laboratory facilities.

At most, the finalization of this proposed test procedure rulemaking should do no more than update the reference to the 2007 edition of ASHRAE 103 and clarify the precision of the AFUE value.

There is a more reasonable option that provides benefit to DOE and our members and has no adverse effect on the current method of determining AFUE ratings for residential boilers and furnaces. The July

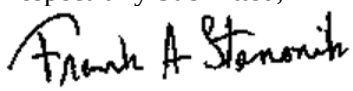
10, 2013 final rule established a new version of the efficiency test procedure for residential furnaces and boilers. Consequently, DOE's review and possible amendment of the current test procedures does not have to be completed until July 2020. In a related matter, ASHRAE Standard 103-2007 is being revised. The proposed ASHRAE Standard 103-2015 will be issued for public review within the next few months. The result of this process will be a new edition of ASHRAE Standard 103 issued sometime in 2016. The amendments being proposed for this new edition include set-up and testing changes to improve:

- The definition of inlet and outlet ducts sizes;
- The specifications for duct and plenum arrangements;
- The way static pressure is measured; and
- The definition of operating conditions: combustion air temperature and humidity return air temperature and humidity, and room temperature.

We recommend that DOE withdraw this NOPR on the basis that it is not required in order for DOE to comply with its statutory obligations and the recognition that in order to properly proceed with its efficiency standards rulemakings, DOE needs a finalized test procedure that will not change during the course of those rulemakings. We further recommend that DOE reschedule this rulemaking to amend the furnace/boiler efficiency test procedure to start sometime after the new edition of ASHRAE Standard 103 has been published, with the stated intent to update the reference in the DOE test procedure to that new edition. This recommendation assumes that the reinitiation of the test procedure rulemaking will occur well after the rulemakings to revise the minimum efficiency standards for residential boilers and gas furnaces have been finalized. DOE's intent in this test procedure rulemaking was not to incorporate amendments that change AFUE ratings. The withdrawal of this NOPR does not in any way undermine that intent nor does it adversely affect manufacturers, consumers and other interests. We urge DOE to accept this recommendation.

AHRI appreciates the opportunity to provide these comments. If you have any questions regarding this submission, please do not hesitate to contact me.

Respectfully Submitted,



Frank A. Stanonik
Chief Technical Advisor

Attachment A

Attachment A

AHRI Residential Boiler (RBLR) Tests
Proposed DOE Amendments

Executive Summary

The report is the result of a project to conduct tests on selected RBLR models to evaluate the effects of the changes the U.S. Department of Energy is proposing to its test procedures for RBLRs due to the adoption of the 2007 version of ASHRAE 103 and modified burner setup instructions. Specifically, the testing project evaluated the impact of changes being proposed to the burner setup instructions (CO_2/O_2) and the on/off times for the cyclical condensate test. Testing in this report was conducted on RBLR models that were selected for annual testing as part of the AHRI Residential Boiler certification program.

The current DOE test procedures allow flexibility to setup the burner with various air/fuel ratios, and the proposed rule narrows down the setup to a CO_2 target within the midpoint of a range specified by the manufacturer's installation and operations (I&O) manual. The goal of the testing was to demonstrate that the changes in excess air during the testing has a significant impact on the resulting AFUE, and that the setup instructions proposed by DOE will result in a lowering of AFUE in most boilers when compared to common practice to rate the efficiency of boilers at higher allowable CO_2. The testing also attempts to quantify the impact and determine the significance of the changes to the 2007 cyclical condensate test.

The experiment showed a significant AFUE decrease with a decrease in CO_2. This is an expected result from theoretical physics, as decreased CO_2 means increased air dilution, reduced heat transfer from flue gas to boiler water, and lower efficiency. The magnitude of change observed in four data points was 0.30 percent AFUE per percent CO_2. As the proposed burner setup instruction would require most manufacturers to reduce the CO_2 basis for AFUE, the proposed change would result in a significant decrease in most AFUE ratings. More data could potentially demonstrate a greater impact of changing CO_2 on AFUE, so the actual impacts could be much greater.

The changes in the cyclical condensate on/off times resulted in minor variations in AFUE ratings. The testing evaluated the change in AFUE as a result of using ASHRAE 103-2007, as well as the impact of the new on and off times for the cyclical condensate test by evaluating the resulting values of the Latent Heat Gain Under Part-Load Conditions, L_G. The impact on AFUE is a combination of the new result for L_G and revised calculations based on the modified on/off times. The review of the tests on two condensing boilers showed that L_G value changed an average of 0.07% under near-identical conditions. Although this is limited data, it indicates that this difference may not be significant enough to require retesting to determine new values of L_G per the ASHRAE 103-2007 test procedure. Note: with the exception of the cyclical condensate test (ASHRAE 103 Section 9.8), the AFUE per ASHRAE 103-2007 can be calculated from data collected per the current DOE test procedures.

Selection of Test Samples

A working group of the AHRI Hydronics Institute Technical Committee met and selected models for the additional testing project from models planned for testing at Intertek as a part of the 2015 RBLR certification program. Models were selected based on the sample's ability to test at different CO_2 values for various burner setup procedures and having a variety of boiler types and manufacturers. The three tested samples were manufactured by three different manufacturers. Three different burner setup conditions were considered:

- **Current AHRI Burner Procedure** – Adjust the High Fire CO_2 to within ±0.1% of the basis of ratings and in accordance with the acceptable range specified in the installation and operation (I&O) manual. If the basis of rating is outside the acceptable range, setup burner to within ±0.1% of the maximum/minimum allowable CO_2 range nearest to the basis of ratings.
- **DOE-proposed Burner Procedure** – Adjust the combustion airflow to achieve CO_2 to within the middle 30th percentile of the acceptable range specified in the I&O manual. In this case, testing was performed as close to the actual midpoint of this range as practical.
- **CO_2 Basis of Rating Burner Procedure –** Adjust the burner to achieve within ±0.1% of the CO_2 basis of rating.

Table 1 – Selected Sample Attributes and Burner Settings for CO_2

	Fuel Type	Type	CO_2 Range in I&O Manual (%)	CO_2 settings for Test (%)		
				Current AHRI Procedures for 1993 & 2007 Test	DOE-proposed Procedures for 2007 Test	At CO_2 basis of Ratings for 2007 Test
Sample #1	Natural Gas	Condensing	9-10.5	10.4	9.75	10.6
Sample #2	Natural Gas	Condensing	8-10.5	10.4	9.25	10.4*
Sample #3	Light Oil	Non-Condensing	11-13	12.8	12.15	12.8*

* Identical to current AHRI procedures and therefore no additional testing was required.

Test Procedures

Each test type was categorized based on the test procedures that were conducted and the reports that were created. A matrix of each test category is shown on Table 2.

The AHRI-93 test fulfilled the requirements of the 2015 AHRI certification program and provided performance data of the sample as tested to ASHRAE 103-1993 with the current AHRI burner setup procedures.

Table 2 – Matrix of Test Procedures and Reports for each Test Category

Test Procedures and Reports				
Test Category	**Procedure Description**	**Sample #1**	**Sample #2**	**Sample #3**
AHRI-93	1993 Test with current AHRI procedures	X	X	X
AHRI-07C	AHRI-93 test data, except for ASHRAE 103-2007 cyclical condensate test, calculated per the 2007 version with current AHRI burner settings	X	X	
AHRI-07NC	1993 test data for a Non-condensing boiler calculated to the 2007 version calculations with current AHRI burner settings			X
DOE-07	2007 test per DOE-proposed burner instructions	X	X	X
CO2BASIS-07	2007 test per ±0.1% CO_2 of the CO_2 basis of rating	X		

The AHRI-07C test analyzed the impact of changes in the ASHRAE 103-2007 would have on AFUE due to changes to both the cyclical condensate test and the calculations. An additional cyclical condensate test to the 2007 procedures was conducted at the current AHRI burner setup procedures. The AHRI-07C test report was calculated using the 2007 cyclical condensate data with the 1993 test data for the current AHRI burner setup procedure.

The AHRI-07NC calculation analyzed changes in ratings on a non-condensing boiler due to the calculations used in ASHRAE 103-2007. The 1993 test data from a non-condensing test was recalculated using ASHRAE 103-2007 calculations.

The DOE-07 test investigated the impact of the DOE proposed burner setup instructions on AFUE when tested to ASHRAE 103-2007. DOE proposes setting up combustion air flow in the burner to achieve an excess air ratio to within the middle 30th percentile of the acceptable range specified in the I&O manual. All burners were setup as close to the actual midpoint of the CO_2 range specified in the I&O manual as possible and tested to the ASHRAE 103-2007 test procedure.

The CO2BASIS-07 test evaluated the impact on AFUE ratings if the 2007 test was conducted at ±0.1% CO_2 to the burner settings on the test of record. When a model is certified in the AHRI program, a test of record is supplied to the 1993 procedure to verify the validity of their requested ratings. The burner settings used on the test of record are reproduced to within ±0.1% of the test of record and tested to the 2007 test procedure. The CO2BASIS-07 test shows AFUE ratings for a 2007 test when setup with similar burner settings to those use to initially establish the basis for the ratings.

Test Results

Sample #1 (Condensing, Step-Modulating, Natural Gas):

The test results on Sample #1 are provided as Figure 1. The baseline ASHRAE 103-2007 test (AHRI-07C) was tested with a burner setup to 10.42% CO_2 and resulted in an AFUE of 91.970%. When the burner was reset and tested to the lower CO_2 value of 9.75%, per the DOE-proposed burner settings, it (DOE-07) resulted in an increase of 0.167% AFUE in comparison to the baseline test. A final test was conducted at the highest CO_2 setting of 10.58%, and the test resulted in a highest AFUE value of all the tests at 92.641% AFUE.

Additionally, the adoption of the 2007 cyclical condensate on/off times showed a slight increase in AFUE for Sample #1. The AHRI-07C test calculated the AFUE with the cyclical condensate test performed with on/off times from ASHRAE 103-2007 resulted in an increase of 0.226% AFUE.

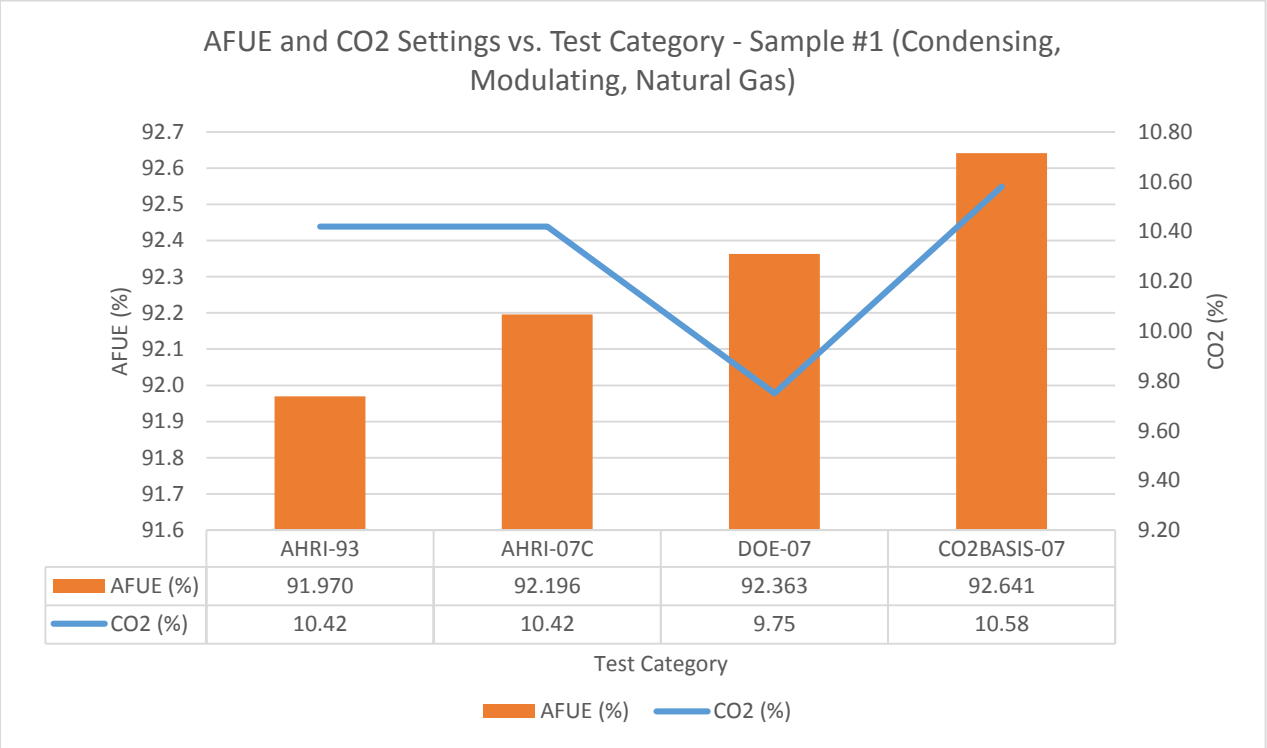


Figure 1 – AFUE and CO_2 Test Results for Sample #1 (Condensing, Step-Modulating, Natural Gas)

Sample #2 (Condensing, Step-Modulating, Natural Gas):

The test results on Sample #2 are provided on Figure 2. The baseline ASHRAE 103-2007 test (AHRI-07C) was tested with a burner setup to 10.38% CO_2 and resulted in an AFUE of 92.905%. When the burner

was reset and tested to the lower CO_2 value of 9.25%, per the DOE-proposed burner settings, the test data (DOE-07) showed a decrease of 0.426% AFUE in comparison to the baseline AHRI-07C test. The test data for Sample #2 showed that decreased excess air fuel ratios had a direct correlation to the decreased AFUE ratings found on the DOE-07 test.

The comparison of the 2007 cyclical condensate on/off times for Sample #2 showed an insignificant change to the AFUE. A change of 0.03% was observed from the change to the cyclical condensate on/off times from ASHRAE 103-2007.

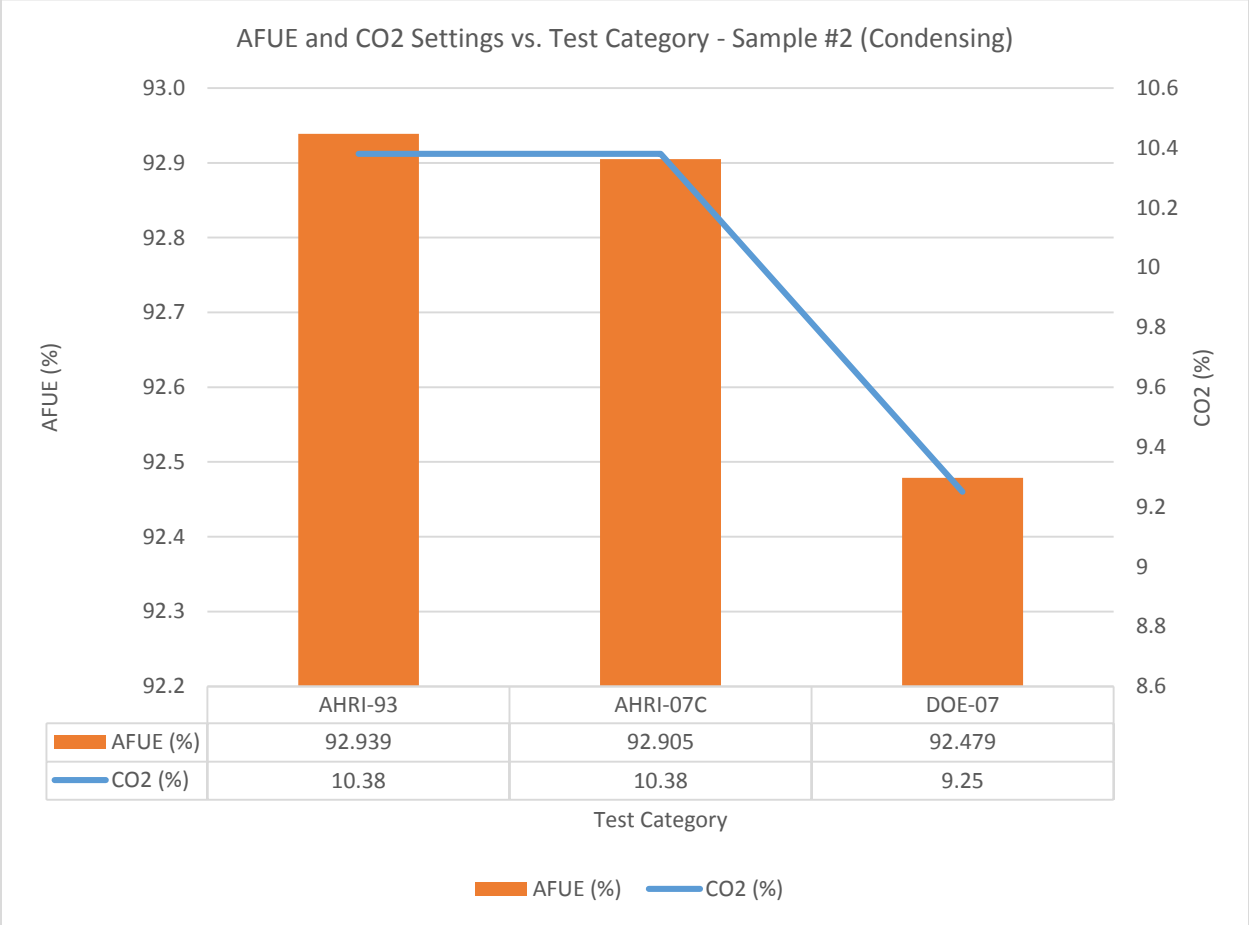


Figure 2 – AFUE and CO_2 Test Results for Sample #2 (Condensing, Step-Modulating, Natural Gas)

Sample #3 (Non-Condensing, Single-stage, Light Oil):

The test results on Sample #3 are shown in Figure 3. The baseline ASHRAE 103-2007 test (AHRI-07NC) was tested with a burner setup to 12.8% CO_2 and resulted in an AFUE of 86.988%. When the burner was reset and tested to the lower CO_2 value of 12.14%, per the DOE-proposed burner settings, the test data (DOE-07NC) showed a decrease of 0.411% AFUE in comparison to the baseline AHRI-07C test. The AFUE

results for the DOE-07NC test verified our hypothesis that decreases in excess air fuel ratio would decrease AFUE.

The comparison of the 2007 calculations for non-condensing, light oil tests to the 1993 calculations for Sample #3 showed an insignificant change to the AFUE. The AHRI-07NC test showed a decrease of 0.05% AFUE when calculated to the ASHRAE 103-2007 Standard.

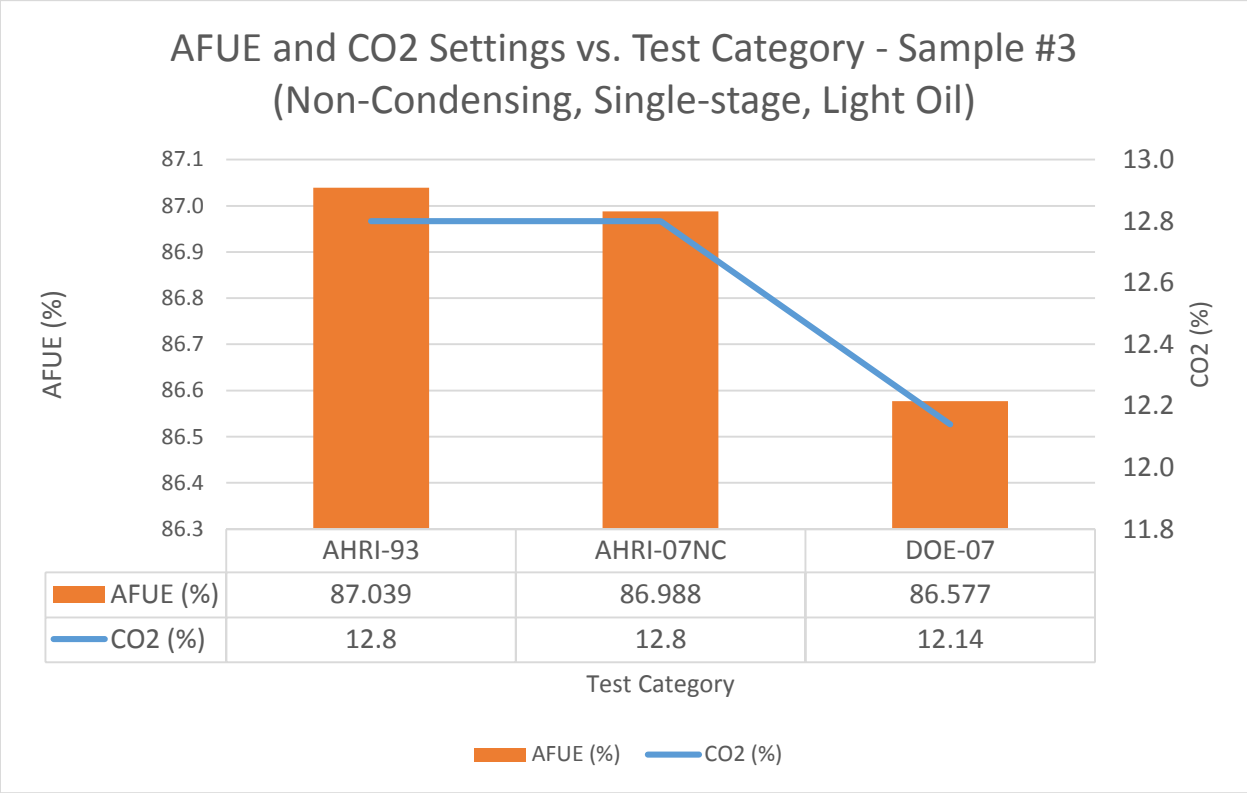


Figure 3 – AFUE and CO_2 Test Results for Sample #3 (Non-Condensing, Single-stage, Light Oil)

Analysis of Results

The testing aimed to 1) demonstrate a significant relationship between CO2 and AFUE, and 2) investigate the significance of the revised cyclical condensate test.

The impact of the burner setup was evaluated by comparing the AFUE results by testing each boiler to various excess air conditions: 1) a baseline that is the current AHRI certification program practice of testing to the maximum CO2 that is allowable in the manufacturer's I&O manual, 2) the current and typical rating practices used by the industry, which are allowed by the current test procedure, and 3) the proposed DOE setup procedure. Table 3 summarizes the changes in AFUE as a result of CO2 changes, as compared to the baseline (AHRI-07).

Table 2 – Summary of Effect of CO_2 Changes on Resulting AFUE per ASHRAE 103-2007

Sample ID	Type	Test ID	CO_2 (%)	AFUE (%)	ΔCO2 from AHRI-07C (% CO_2)	ΔAFUE from AHRI-07C (% AFUE)
1	Natural Gas, step-modulating	AHRI-07C	10.42	92.197	-	-
		DOE-07	9.75	92.348	-0.670	0.151
		CO2BASIS-07	10.58	92.631	0.830	0.283
2	Natural Gas, step-modulating	AHRI-07C	10.38	92.888	-	-
		DOE-07	9.25	92.479	-1.130	-0.409
3	Oil, single-stage	AHRI-07NC	12.8	86.988	-	-
		DOE-07	12.14	86.577	-0.660	-0.411

The resulting differences from the four data points were placed on a scatter plot, and a trendline was fitted to the data (Figure 4). The slope of the trendline was found from a linear regression analysis of the results of testing on these three boilers with the y-intercept of the regression line forced to zero. The regression analysis shows that a 0.30% AFUE change can be expected from each percent CO_2 change. The r-squared value of this trendline is $R^2 = 0.564$, which shows a strong significance of this relationship.

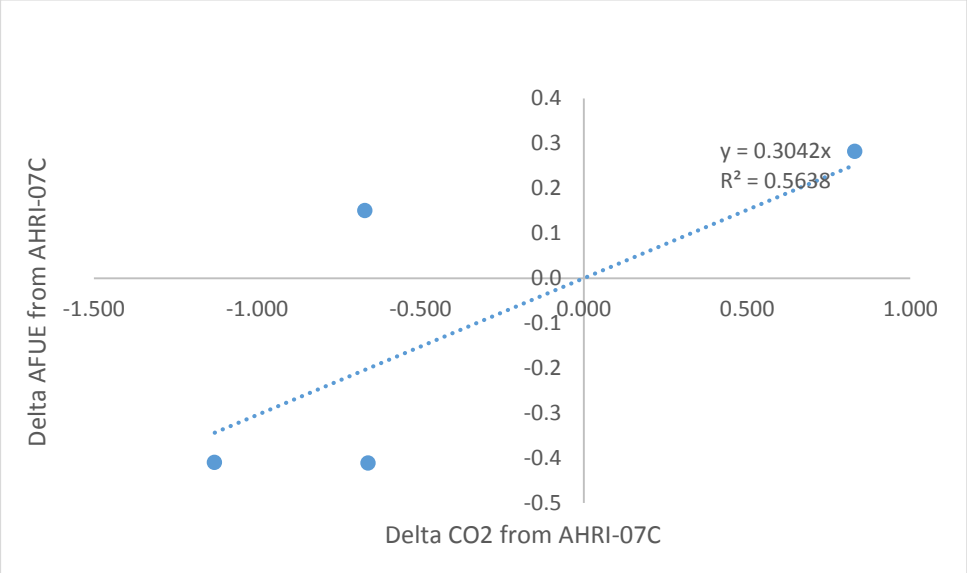


Figure 4 – Scatter Plot of Changes in AFUE and CO_2 from Testing, with Trendline

The test results on the condensing boiler models were further analyzed to determine the impact on AFUE resulting solely from the proposed change in the cyclical condensate test, as described in ASHRAE 103-2007. The current test procedure defines both on and off times as 15 minutes each, and the cyclical condensate test is performed with those on and off periods. In the proposed procedure, the actual on and off times during the test would be determined by a calculation that is a function of the ratio of high- and reduced-fire output capacities. The cyclical condensate test provides two measurements: mass of condensate, M_C, and heat input, Q_C. These values are then used to calculate (ASHRAE 103-2007 Section 11.3.11.1) the Latent Heat Gain Under Part-Load Conditions, L_G. The resulting values of L_G from the 1993 and 2007 versions of ASHRAE 103 are provided in Table 3.

Table 3 – Summary of L_G Results from ASHRAE 103, by revision edition, Testing on Condensing Boilers

Sample #	L_G – 1993 (%)	L_G – 2007 (%)	ΔL_G
1	3.1289	3.4555	0.3266
2	3.9967	3.8051	-0.1916
		Average	0.0675
		σ_{sample}	0.366

The resulting L_G does not have a one-for-one impact on AFUE. For step modulating boilers, which constitutes the majority of condensing boilers, the cyclical condensate test and L_G result is only applicable to the reduced firing rate. The L_G value is used to calculate the Part-Load Efficiency at the Reduced Firing Rate, $Effy_{U,R}$, and its value is added directly to the $Effy_{U,R}$. However, the impact of $Effy_{U,R}$ on AFUE is proportional to the Fraction of Part-Load Operation, X_R, per Equation 11.5.11.3 (note that AFUE equals Heating Seasonal Efficiency for furnaces and boilers with no standing pilot):

$$AFUE = (X_H)Effy_{U,M} + (X_R)Effy_{U,R}$$

Since $Effy_{U,R}$ changes on a one-for-one basis with a change in L_G, multiplying L_G by X_R will indicate the expected change in AFUE. The resulting product of ΔL_G and X_R, which is calculated per ASHRAE 103-2007, is assumed to represent the AFUE change due to the different results in the cyclical condensate test. Table 4 shows the resulting expected change in AFUE as a result of the proposed change in the cyclical condensate test.

Sample #	ΔL_G (%)	X_R – 2007 (-)	$\Delta L_G * X_R$ (% AFUE)
1	0.3266	0.533	0.17407
2	-0.1916	0.283	-0.05423
		Average	0.0599
		σ_{sample}	0.1614

Conclusion

Testing was performed on three boilers to evaluate the impact of DOE proposed changes to the burner excess air settings and the changes to the cyclical condensate test.

The analysis of CO_2 changes showed a significant impact of burner setup on the resulting AFUE. The DOE proposed burner setup requirements will require manufacturers to retest their products in many cases to match the new CO_2 rating specified by DOE. In many of those cases, the manufacturer will be required to rate with a lower CO_2 than currently used. The models chosen for this testing was limited by those already selected for AHRI certification, so the magnitude of this change was no more than 1.5 %CO2; however, in reality the required CO_2 change in rerating could be much more. Given the relationship demonstrated by this testing, the proposed burner setup instructions cannot be viewed as a neutral change from the current test procedures.

The results of the cyclical condensate tests resulted in small changes in AFUE. These two data points suggest that the impact of changing the cyclical condensate test for modulating boilers might not be significant enough to justify the added testing burden. More data should be evaluated prior to requiring this change to determine the significance of this proposed change. An alternative path that could be considered is to maintain the ASHRAE 103-2007 calculations as written, but to revise ASHRAE 103-2007 Section 9.8 so that the cyclical condensate test uses the on/off times from ASHRAE 103-1993 (15 minutes each). This would obviate the need for new testing, which address the major concern of manufacturers, but new calculations could still potentially result in new AFUE ratings for equipment.