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2311 Wilson Boulevard Suite 400 Arlington VA 22201 USA
Phone 703 524 8800 | Fax 703 562 1942
www.ahrinet.org

May 31, 2019

Ms. Jennifer Tiedeman
U.S. Department of Energy,
Office of the General Counsel,
GC–33, 1000 Independence Avenue SW,
Washington, DC 20585–0121

Re: Request for Information on the Measurement of Average Use Cycles or Periods of Use in DOE Test Procedures, *Docket EERE–2018–BT–TP–0020*

Dear Ms. Tiedeman:

These comments are submitted by the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) in response to the U.S. Department of Energy (DOE) Request for information (RFI) regarding measurement of average use cycles or periods of use in DOE test procedures appearing in the *Federal Register* on March 18, 2019. AHRI joins the "Joint Commenters" substantive comments and fully supports all positions included therein. We file these comments under separate cover to highlight some specific test procedure challenges that are important to the HVACR industry.

AHRI is the trade association representing manufacturers of heating, cooling, water heating, and refrigeration equipment. More than 300 members strong, AHRI is an internationally recognized advocate for the industry and develops standards for and certifies the performance of many of the products manufactured by our members. In North America, the annual output of the HVACR and water heating industry is worth more than $44 billion. In the United States alone, the HVACR and water heating industry supports 1.3 million jobs and $256 billion in economic activity annually.

In response to the "The Proposed Process Rule" AHRI provided DOE substantive information regarding specific instances where DOE test procedures' methods of measuring energy use have become unnecessarily complex, potentially incorporating the testing of modes and/or functions that do not, in fact, produce results that are representative of average use cycles or periods of use.[1] In the Process Rule comments, AHRI noted that some DOE test procedures have presented challenges that add burden without value. Others test procedures are ambiguous, causing unnecessary uncertainty. AHRI and its members execute hundreds of test annually. This experience has identified errors or practical challenges in procedures. We again submit our request that DOE address the following concerns in future rulemakings or, preferable, by interpretive rule:

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[1] AHRI Comments to the Proposed Procedures for Use in New or Revised Energy Conservation Standards and Test Procedures for Consumer Products and Commercial/Industrial Equipment, Docket ID No. EERE-2017-BT-STD-0062

1. Furnace fan test procedure clarifications, and
2. Central air-conditioning and heat pump test procedure calculation corrections.

AHRI comments to the Process Rule and details regarding the concerns, above, are attached (Exhibit-1). In addition to the above concerns, some additional items citing provisions in the Department's test procedures for consumer appliances and industrial equipment that could be improved to produce results that are more representative of average use cycles or periods of use are below.

Furnace fan test procedure clarifications

AHRI has consistently maintained that the furnace fan test procedure double counts cooling hours and that DOE had misinterpreted the relevant provision of EPCA used to include those hours. The heading of 42 U.S.C. 6295(f) entitled, ‘‘standards for furnaces and boilers’’ and subsections 1 through 4 under that section apply only to residential furnaces and boilers, as defined by EPCA. This clear, consistent format strongly indicates that the scope of this requirement includes only the motor and blower combinations provided in residential warm air furnaces. There is nothing within section 42 U.S.C. 6295(f) that suggests that the provisions of that section apply to any other products that may be used to heat a residence. If the intent of this change had been to include circulation fans used in residential air conditioners and heat pumps, then Congress would have added a corresponding paragraph to 42 U S C. 6295(d)—the section covering central air conditioners and heat pumps. Central air conditioners and heat pump products like split-system packaged central air conditioners and heat pump air handlers should be excluded because the electrical consumption of their circulation fans is already addressed in the seasonal energy efficiency ratio (SEER) and heating seasonal performance factor (HSPF) descriptors. AHRI's position remains that including the cooling or circulating functions in the FER test procedure do not, in fact, produce results that are representative of average use cycles or periods of use of a furnace.

Fan energy

DOE requested comment on whether imposing ventilation or fan efficiency requirements would constitute double-regulation and “‘additive of other existing accounting of fan energy use’’ for water-source heat pumps (WSHP) and for single package vertical units (SPVU).[2] AHRI's brief response is that the cooling mode of the product is the operational average use cycle – the fan energy is counted during this cycle, and that additional ventilation testing or performance requirements constitute double regulation.

While WSHPs and SPVUs provide some level of ventilation from time to time, the primary function is cooling, and heating in the case of WSHP. AHRI is not aware of any field

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[2] Refer to AHRI Comments in Response to Department of Energy's Request for Information Regarding the Test Procedure for Water-Source Heat Pumps, Docket Number EERE–2017–BT–STD–0029, and AHRI Comments in Response to Department of Energy's Request for Information Regarding the Test Procedure for Single Package Vertical Air Conditioners and Single Package Vertical Heat Pumps, Docket Number EERE–2017–BT–STD–0020.

applications where a WSHP or SPVU is used primarily for ventilation. Put more simply, neither WSHPs nor SPVU are fans. Given that DOE is limited to one metric per product, the “representative average use cycle” for these products should concentrate on the bulk of energy used during heating or cooling rather than the occasional and ancillary fan-only ventilation utility.

The current metrics for these products take into account the fan watts of the blower-motor packages used in each product. And these metrics are already driving energy savings by serving as an overall minimum for the equipment’s energy use, while allowing the manufacturer to determine how best to meet that minimum. A key goal of the prohibition on setting separate standards for components is to allow the manufacturer to innovate in meeting energy use standards for a product – and that goal is being met here. Moreover, imposing component standards would contravene EPCA’s one-metric per product limitation while, in effect, imposing impermissible design standards on the final product. In sum, setting additional minimums for supply fans or fan energy use during a ventilation cycle or other field applications would undermine good policy and exceed DOE’s authority.

AHRI acknowledges that DOE has the authority to include certain fans and blowers, by rule, as “covered equipment” if such products meet all the requirements of 42 U.S.C. § 6311(2). However, DOE has not taken any procedural steps to do so. Further, even if DOE developed a standard for stand-alone industrial fans, it would not be appropriate to apply that standard to fans embedded in regulated equipment.

First, Section 6312 limits DOE’s authority to regulate as covered industrial equipment certain articles that are also components of consumer products. The blower-motor combination used by WSHPs and other commercial AC and HP equipment is precisely the kind of component that is protected from double-regulation by Section 6312. This provision is intended to restrict DOE’s authority to regulate articles that are principally sold as component parts of consumer equipment. Certain large and very large industrial fans may qualify as covered equipment under this definition, but the blower-motor combinations in WSHPs, SPVUs, and commercial air conditioners are identical to the components of central air conditioners. Moreover, these products are not independently available on the open market and do not serve an independent energy-using function apart from as a component of air conditioners.

Second, DOE’s authority to regulate components is based on *necessity*. Sections 6312(b) and (c) state, in relevant part, that DOE may, by rule, include as industrial equipment articles which are component parts of consumer products, only if it concludes that doing so “is *necessary* to carry out the purposes of this part.” (Emphasis supplied). Adding a fan metric to the current requirement is not *necessary*, because WSHPs already have an overall energy efficiency requirement. If DOE seeks to improve the energy efficiency of WSHPs, then it has a viable existing mechanism: the overall product minimum standards. The addition of a ventilation or fan requirement is classic double regulation and is not “necessary” within the meaning of EPCA.

Finally, unlike the specific provision applicable exclusively to consumer furnace fans, DOE has no alternative authority to impose additional ventilation metrics or requirements on top of the product efficiency metric and standard. The fact that Congress was compelled to grant a specific provision of authority for a consumer furnace ventilation metric affirms DOE is without general authority to create overlapping ventilation requirements for any other regulated products.

Building design may be too complex to be averaged

Just as behavioral data should be national in scope, so should climatic conditions. Climate in one part of the country should not be an assumed proxy for the rest of the country. Field default settings, or "as shipped" settings, for multiple stage or variable speed equipment do not capture climate, average use, or even average installation.

There are 17 climate zones in the United States per ASHRAE Standard 169, *Climate Data for Building Design Standards*, varying from very hot and humid to very cold. While these location-specific conditions are accounted for during the design of a particular building, the point of an energy efficiency standard is to be able to compare products using a single metric. For residential heat pumps, products are compared based on performance in Region IV. The field default setting may not be for Region IV, depending on the product's target market.

Commercial buildings have significantly different load profiles ranging from a lightly loaded office building to a commercial kitchen or data center. Different equipment types have different use application distributions as well. Energy efficiency metrics should be reviewed periodically to ensure that they capture the average use of these varying applications, but any changes should only be made with supporting data. Finally, another challenge is what features to include in the unit or system. There has been a push to include ventilation energy into metrics; however, building ventilation can be accomplished through different strategies. For example, the building can be ventilated through a rooftop unit or through a dedicated outdoor air system (DOAS). Many big-box retailers, for example, bring in outdoor air through a DOAS and cycle the fans on commercial units to save energy. Additional energy-savings features that are implemented differently in different buildings, depending on design are air, water and refrigerant free-cooling, energy recovery ventilators, evaporative cooling, and fan-power terminals. Simply put, climate, building use, and a product's field settings cannot be averaged. While the current federal efficiency metrics have their limitations and can be improved over time, they provide a basis for equipment-to-equipment comparison under controlled conditions, something that is relatively cost effective for the purposes of DOE enforcement or assessment testing as well.

Typical energy efficiency metrics not appropriate for modeling

The objective of an energy efficiency metric is to compare like products, originally on the basis of mechanical cooling efficiency for cooling-products. Recent efforts have sought to expand ratings to include ventilation; however have ignored economizers, DOAS separate equipment, controls for supply air reset, static pressure reset, setback and setup and other systems losses, duct leakage, and duct heat transfer losses – in other words, the system. System analysis requires system tools. The current approach of using metrics for models is extremely inaccurate and full maps like ASHRAE 205 are requirements and even the current Energy Plus models have significant issues. Current system tools that are in the nascent stages of development and not accurate enough for regulatory purposes.

We acknowledge that full load metrics may not be appropriate in the future; however, analysis should be done on a product-by-product basis, balancing the needs of product differentiation with test burden, with industry leading the effort.

Test procedure review needs to be done on product-by-product basis

We support DOE examining the average-use cycles on a case-by-case basis to ensure that innovative designs are properly accounted for and valued in the in the test procedure and metric. The waiver process, currently being streamlined, provides an opportunity for manufacturers with innovative products to create a bridge between current test procedure and advancements in technology and equipment innovations made by industry. In cases where waivers have been approved, the average use cycles or the methodology accounting for such needs to be evaluated to ensure that the proper accounting is done without prescribing a test procedure that is unduly burdensome to conduct.

As previously noted, the primary use of the energy-efficiency metrics is for apples-to-apples comparisons of competing equipment in the marketplace. We urge DOE to investigate, on a product-by-product basis, and support with data, how the industry test procedure, metric, technologies, and use have changed over time. In many cases, creative solutions are needed to ensure that the test burden remains at a reasonable level, while capturing the advancements in technology in a repeatable, reproducible, and representative manner. We do not believe it is suitable for DOE to issue a wide-arching interpretation with regards to the “average use cycle” requirements in the statute, but instead make a commitment to work with industry and other interested stakeholders during each product test procedure rulemaking to ensure that the current metric and methodology are repeatable, reproducible, representative, equitable, and not unduly burdensome to conduct. A narrow interpretation of the “average use cycle” language for reviewing and revising test procedures, where ambiguities, insufficiencies, innovative technologies, repeatability, and equitable representations need to be addressed is not a desired outcome.

If you have any questions regarding this submission, please do not hesitate to contact me.

Sincerely,

Laura Petrillo-Groh, PE
Lead Regulatory Advisor, Cooling Technology
Direct: (703) 600-0335
Email: LPetrillo-Groh@ahrinet.org

Exhibits:

1. AHRI comments to Proposed Procedures for Use in New or Revised Energy Conservation Standards and Test Procedures for Consumer Products and Commercial/Industrial Equipment, Docket ID No. EERE-2017-BT-STD-0062

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& REFRIGERATION INSTITUTE
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2311 Wilson Boulevard Suite 400 Arlington VA 22201 USA
Phone 703 524 8800 | Fax 703 562 1942
www.ahrinet.org

Ms. Sofie Miller
U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
1000 Independence Avenue SW
Washington, DC 20585
Telephone: (202) 586-5000
E-mail: *Process.Rule@ee.doe.gov*.

Re: Proposed Procedures for Use in New or Revised Energy Conservation Standards and Test Procedures for Consumer Products and Commercial/Industrial Equipment

Docket ID No. EERE-2017-BT-STD-0062

Dear Ms. Miller:

The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) is pleased to submit comments on the Proposed Procedures for Use in New or Revised Energy Conservation Standards and Test Procedures for Consumer Products and Commercial/Industrial Equipment (hereafter "The Proposed Process Rule" or "Proposal") (84 *Fed. Reg.* 3910 (February 13, 2019)). AHRI joins the "Joint Commenters" substantive comments and fully supports all positions included therein. We file these comments under separate cover to highlight some specific test procedure challenges that are important to the HVACR industry.

AHRI represents more than 300 manufacturers of air conditioning, heating, and commercial refrigeration equipment. It is an internationally recognized advocate for the HVACR industry and certifies the performance of many of the products manufactured by its members. In North America, the annual output of the HVACR industry is worth more than $20 billion. In the United States alone, AHRI members employ approximately 130,000 people, and support another 800,000 dealers, contractors, and technicians.

In recent years, some DOE test procedures have presented challenges that add burden without value. Others are ambiguous, causing unnecessary uncertainty. AHRI and its members execute hundreds of test annually. This experience has identified errors or practical challenges in procedures. We request that DOE address the following concerns in future rulemakings or, preferable, by interpretive rule:

1. Furnace fan test procedure clarifications (Exhibit 1)
2. Central air-conditioning and heat pump test procedure calculation corrections (Exhibit 2)
3. Water heater recovery energy efficiency calculations (Exhibit 3)
4. Instantaneous water heater test procedure tolerances (Exhibits 4 & 5)

Furnace fan test procedure clarifications

In 2017, AHRI submitted a request for guidance on how to execute the furnace fan test procedure. The Department provided some helpful responses, but one particular issue remains unclear. Since 2017, AHRI, its members, and third-party laboratories have run numerous FER tests. Test results on identical models vary significantly depending on how the test lab interprets set-up instructions contained within the CFR.

The provision causing the most concern relates the selected motor speeds controlling air-flow at various modes of operation, or "speed taps." The speed of the motor is set to operate differently when the unit is in different modes—heating, cooling, and constant circulation. For example, the air flow is generally higher in cooling mode than in heating mode. The motors speeds are first set in the factory to accommodate the typical installation setting but can be changed by the installer in the ,field depending on necessary conditions. These adjustments are described in the manufacturers' installation and operations manuals (I&O manuals). For example, a "max" air-flow setting is sometimes available if a particular home has a back bedroom that requires a "boost" of air flow to ensure that the room farthest from the unit is still appropriately conditioned. However, the "max option" is not intended for most settings. This is important because, as discussed below, the fan test requires the default settings, but also requires the highest available setting for each mode. Reasonable minds have disagreed on what exactly the test procedure is directing.

First, the test procedure directs the lab to run the test at the "default" setting for air-flow. To the average laboratory (and person), "default" settings are the factory settings to which the product is set as shipped. However, further reading of the test procedure identifies the "default" settings to be the "highest specified setting for each mode," which is often different from the factory settings.

Second, all products' instruction and operations manuals are different. Some I&O manuals specify the highest speed setting for each operating mode: cooling, heating, and constant circulation. Many I&O manuals only specify one set of air-flow settings for the product. During a performance test—and as installed in the field—only one "speed tap" or air-flow setting can be assigned per mode. In most field installations, the highest speed is set for cooling, the next highest is selected for heating, and the next highest is set for constant circulation mode. In no circumstances will the air-flow for heating and cooling set at the same motor speed. The factory controls do not allow for that set up because the mode controls are connect by wire to a single port assigned to air-flow speeds (i.e., speed taps). Where the manual specifies only one air-flow table, ambiguity arises. Manufacturers have options: they can select the highest speed tap for cooling, the second highest for heating, and third for constant circulation. One wire per port, one speed tap per mode. In the alternative, one could interpret the test procedure to require that a "jumper wire" is introduced to allow for the test to be run at the highest speed setting for all three operational modes. This is not an impossible setting in the field, but it is unusual.[1]

The ambiguity and multiple set-up interpretations are causing variances in test results on the same model. The uncertainty is wasteful for industry. AHRI has requested guidance on this interpretation in the past, and DOE indicated that a jumper wire was not required, but no explicit opinion was provided about whether other various interpretations by manufacturers were appropriate. Among industry's concerns is that DOE will initiate enforcement testing and DOE will execute the test differently than the manufacturer or third-party laboratory, causing a seemingly compliant product to fall out of compliance. Another concern is that two manufacturers will come to different conclusions, and the test results will not be comparable. Any definitive guidance that the Department can provide will be valuable to our manufacturers.

<u>Central Air-Conditioning and Heat Pump Test Procedure Calculation Corrections</u>

AHRI has identified some ambiguities in the central air conditioning and heat pump test procedure at Appendix M. We have interpreted the test methods based on the most reasonable reading of the language. In order to reduce uncertainty, AHRI is seeking guidance on whether the interpretations included in Exhibit 2 align with DOE's technical understanding of the test procedure.

In addition, in preparation for a new test procedure and new standards effective in 2023, manufacturers have been conducting testing and calculating their ratings using the equations in the test procedures published in Appendix M1. In that process, we have identified some necessary calculation amendments and

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[1] The issue is more technically complicated that described in these comments, a more fulsome description of the interpretation challenges is attached at Exhibit 1.

ambiguities. AHRI's proposed changes are technical in nature and are attached as Exhibit 2. AHRI requests an opportunity to further engage the department, and other interested parties, to describe in better detail the perceived challenges and proposed fixes to the test procedures.

Water Heater Recovery Efficiency Calculations

AHRI members have noted errors in the calculation for recovery efficiency of residential gas, oil, and heat pump storage-type water heaters with a rated storage volume greater than or equal to two gallons (10 C.F.R. §430, Subpart B, Appendix E, Section 6.3.2). Namely, the calculation requires the averaging of water temperatures measured from the start of a 24-hour test to the end of the recovery period. Manufacturers' experiences has determined that averaging of temperatures across the 24-hour test through the recovery period artificially inflates certain test results. The relevant ASHRAE committee has also reviewed manufacturers' test data and agrees that an adjustment to the recovery efficiency calculation will render more accurate results. ASHRAE Standard Project Committee 118.2 has included amended calculations in the most recent draft of its standard, *Method of Testing for Rating Residential Water Heaters*. The standard is currently a draft and will shortly be sent out for public review and comment. AHRI requests that DOE update its test procedure to include the amended calculations at Exhibit 3. In the alternative, AHRI recommends that DOE incorporate the amended recovery efficiency calculations from the ASHRAE 118.2 method of test once that standard is published.

Thermal Efficiency of Storage-type Instantaneous and Instantaneous Water Heaters

Manufacturers' testing experience with the thermal efficiency test for instantaneous (and storage-type instantaneous) water heaters demonstrates that two tolerances are set too tightly, which unnecessarily invalidates tests that would otherwise be technically valid. The pertinent tolerances are gallon per minute flow rate and supply water temperature. (Section 5.1.1, Appendix A and 6.1.1 Appendix C). A single source generates the water feeding the tested equipment, which is looped to several test stations. If one test station is turned on or off or the temperature is adjusted, then the other tests' conditions will be impacted just enough to fail the tight tolerances. The momentary impacts are not unlike someone flushing a toilet in the basement bathroom while someone else is taking a shower upstairs. The person in the shower will notice, but the shock is temporary. Because all of the tested equipment is fed from the main water supply, if one station is turned off affecting water pressure or temperature, other tests occurring at that time may be rendered invalid. After conducting multiple tests, AHRI's third-party laboratories have determined that the only means of meeting the tight tolerances is to create individual water sources for each test station, which is cost prohibitive. The plumbing for the test stations would have to be entirely rebuilt.

AHRI collected data from twenty-seven tests to gauge the appropriate tolerances for flow rate and water temperature for these types of models. The proposed alternatives are included as Exhibit 4 and Exhibit 5. The alternative approach provides an equally representative measure of the thermal efficiency of these models, while ensuring that time and resources are not lost on invalid test. AHRI requests that the Department amend the test procedure or issue an interpretive rule that permits for the successful execution of the thermal efficiency test that is less burdensome, but equally representative of energy efficiency.

We appreciate the Department's consideration of the above amendments and look forward to providing more information as needed.

Sincerely,

Caroline Davidson-Hood
General Counsel

Exhibit 1

FER Airflow Selection Scenarios

The following 13 scenarios show AHRI members' interpretations of how the airflow selections will be made during the FER test for various types of units. These interpretations are based on the content of the DOE FER test procedure, DOE's responses to AHRI's Request for Guidance on the FER test procedure, and conversations that AHRI member companies have had with DOE staff regarding the FER test. All scenarios are based on product literature for actual models in commerce today.

We ask that DOE staff review the interpretations and respond whether they agree or disagree with each. For the interpretations that DOE disagrees with, we ask that DOE staff state why they disagree and state how the selection should be made.

Scenario 1. The condensing gas furnace is manufactured and shipped with the Black motor speed tap connected to the control relay that operates during Cooling mode. The Blue motor speed tap is connected to the control relay that operates during Heating mode, and also for continuous fan. The furnace control cannot run the same speed for both heating and cooling, so the max speed for heating can only be the Blue tap. The following table is printed in the installation instruction that is supplied with the furnace:

	External Static Pressure (inWC)							
Speed Tap	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Black	1545	1505	1460	1420	1365	1320	1275	1225
Blue	1375	1330	1275	1225	1175	1125	1075	1025

FER Interpretation:

Max airflow (Q_{Max}) and electrical consumption (E_{Max}) are determined using the Black speed tap in Cooling mode with the ESP adjusted to 0.65-inWC.

Heat airflow (Q_{Heat}) and heating electrical consumption (E_{Heat}) are determined using the Blue speed tap at the resultant airflow and ESP. Q_{Max} is calculated based on the determination of Q_{Heat} from equations in the Appendix AA of Part 430 Subpart B.

Constant circulating airflow electrical consumption (E_{Circ}) is determined to be the same as E_{Heat} because it is the minimum airflow control setting because it is not specified otherwise.

Scenario 2. The condensing gas furnace is manufactured and shipped with the Black motor speed tap connected to the control relay that operates during Cooling mode. The Blue motor speed tap is connected to the control relay that operates during Heating mode. The furnace control cannot run the same speed for both heating and cooling, so the max speed for heating can only be the Blue tap. The Yellow speed tap is a second heating speed or reserve cooling speed that is connected to the control relay that operates during the continuous fan mode. The following table is printed in the installation instruction that is supplied with the furnace:

	External Static Pressure (inWC)							
Speed Tap	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Black	1545	1505	1460	1420	1365	1320	1275	1225
Blue	1375	1330	1275	1225	1175	1125	1075	1025
Yellow	1195	1140	1090	1040	985	930	875	815

FER Interpretation:

Max airflow (Q_{Max}) and electrical consumption (E_{Max}) uses the Black speed tap *(same as scenario 1).*

Heat airflow (Q_{Heat}) and heating electrical consumption (E_{Heat}) uses the Blue speed tap *(same as scenario 1)*.

Constant circulating airflow electrical consumption (E_{Circ}) is determined using the Yellow speed tap at the resultant ESP because it is the lowest airflow-control setting and is not specified otherwise.

Scenario 3. The condensing gas furnace is manufactured and shipped with the Black motor speed tap connected to the control relay that operates during Cooling mode. The Blue motor speed tap is connected to the control relay that operates during Heating mode. The furnace control cannot run the same speed for both heating and cooling, so the max speed for heating can only be the Blue tap. The Yellow speed tap is a second heating speed or a lower cooling speed that is connected to a reserve terminal on the control board that is not operated by a relay. The Red speed tap is a third heating speed or reserve cooling speed that is connected to the control relay that operates during the continuous fan mode. The following table is printed in the installation instruction that is supplied with the furnace:

	External Static Pressure (inWC)							
Speed Tap	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Black	1545	1505	1460	1420	1365	1320	1275	1225
Blue	1375	1330	1275	1225	1175	1125	1075	1025
Yellow	1195	1140	1090	1040	985	930	875	815
Red	1015	955	900	845	780	730	670	615

FER Interpretation:

Max airflow (Q_{Max}) and electrical consumption (E_{Max}) uses the Black speed tap *(same as previous scenarios).*

Heat airflow (Q_{Heat}) and heating electrical consumption (E_{Heat}) uses the Blue speed tap *(same as previous scenarios)*.

Constant circulating airflow electrical consumption (E_{Circ}) is determined using the Red speed tap at the resultant ESP because it is the lowest airflow-control setting and is not specified otherwise.

Scenario 4. The 2-stage condensing gas furnace with an HCR = 0.65 is manufactured and shipped with the Black motor speed tap connected to the control relay that operates during Cooling mode. The furnace control cannot run the same speed for both high- and low-heating and nor can it run the same speed tap for heating and cooling. The Blue speed tap is connected to a reserve terminal, and serves as a second cooling speed or second high stage heating speed. The Yellow motor speed tap is connected to the high-stage heating control relay. The Orange speed tap is connected to the low-stage heating control relay which also serves as the continuous fan operation. The Red speed tap is connected to the reserve tap for a lower low-heating speed option for a case where someone needs the Orange Speed for a 2-ton cooling system.

	External Static Pressure (inWC)							
Speed Tap	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Black	1545	1505	1460	1420	1365	1320	1275	1225
Blue	1375	1330	1275	1225	1175	1125	1075	1025
Yellow	1195	1140	1090	1040	985	930	875	815
Orange	1015	955	900	845	780	730	670	615
Red	945	735	575	520	450	375	325	260

FER Interpretation:

- Max airflow (Q_{Max}) and electrical consumption (E_{Max}) uses the Black speed tap *(same as previous scenarios).*
- Heat airflow (Q_{Heat}) and heating electrical consumption (E_{Heat}) uses low-stage heating. High-stage heating is assumed to be move to the next highest available Blue speed tap, and low-stage is assumed to be moved to the Yellow speed tap, also the next highest available.
- Constant circulating airflow electrical consumption (E_{Circ}) uses the Yellow speed by default. The Red and Orange speed taps are not used.

Scenario 5. The 2-stage condensing gas furnace with an HCR = 0.65 is manufactured and shipped with the Black motor speed tap connected to the control relay that operates during Cooling mode. The furnace control cannot run the same speed for both high- and low-heating and nor can it run the same speed tap for heating and cooling. The Blue speed tap is connected to a reserve terminal, and serves as a second cooling speed or second high stage heating speed. The Yellow motor speed tap is connected to the high-stage heating control relay. The Orange speed tap is connected to the low-stage heating control relay which also serves as the continuous fan operation. The Red speed tap is connected to the reserve tap for a lower low-heating speed option for a case where someone needs the Orange Speed for a 2-ton cooling system. The table in the installation instructions that comes with the furnace specifies to use only the Orange or Red speed taps for low-stage heating.

	External Static Pressure (inWC)							
Speed Tap	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Black	1545	1505	1460	1420	1365	1320	1275	1225
Blue	1375	1330	1275	1225	1175	1125	1075	1025
Yellow	1195	1140	1090	1040	985	930	875	815
Orange†	1015	955	900	845	780	730	670	615
Red†	945	735	575	520	450	375	325	260

† – Must use the shaded speed selection for low-stage heating.

FER Interpretation:

Max airflow (Q_{Max}) and electrical consumption (E_{Max}) uses the Black speed tap *(same as previous scenarios).*

Heat airflow (Q_{Heat}) and heating electrical consumption (E_{Heat}) uses the Orange speed tap for low-stage heating because the manufacturer limits the selections by indication in the speed selection table.

Constant circulating airflow electrical consumption (E_{Circ}) uses the Orange speed tap by default. The Red speed tap is not used.

Scenario 6. 2-Stage Heat, 1-Stage Cool

a. Control Configuration
   i. 1 tap for Hi Heat
   ii. 1 tap for Lo Heat
   iii. 1 tap for Cool-H
   iv. 1 tap for Park

b. Motor configuration
   i. Motor with 3 or 4 taps

c. Factory Settings

Model	Park "A"	Lo Heat "B"	Hi Heat "C"	Cool-H
TUD2B080A9362A	Yellow	Red	Blue	Black

d. Literature doesn't indicate anything regarding Constant Circulation

e. Airflow Table

FURNACE AIRFLOW (CFM) VS. STATIC PRESSURE (i.w.c.)										
Model	Speed Tap	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
TUD2B080A9362A	4-High-Black	1393	1384	1364	1335	1296	1247	1189	1120	1042
	3-Med.-High-Blue	1210	1209	1198	1177	1147	1107	1058	999	930
	2-Med.-Low-Yellow	1046	1052	1047	1033	1008	973	928	873	808
	1-Low-Red	900	903	895	888	869	842	808	766	717

f. Rise Range Table

CFM VS. TEMPERATURE RISE									
	CFM (CUBIC FEET PER MINUTE)								
MODEL	900	1000	1100	1200	1300	1400	1500	1600	1700
TUD2B080A9362A		59	54	49	46	42			

FER airflow selection:
Settings to be operated by Thermostat:

8.6.1 Max airflow control setting conducted in Cooling Mode with Black wire attached to Cool-H Tap.

8.6.2 Constant circulation airflow control in Circ-Mode with Yellow wire attached to Lo Heat Tap.

8.6.3 Heating airflow control in Heat Mode with Yellow wire attached to Lo Heat Tap.

Scenario 7. 1-Stage Heat, 1-Stage Cool

a. Control Configuration
    i. 1 tap for Heat-H
    ii. 1 tap for Cool-H
    iii. 2 taps for Park
b. Motor configuration
    i. CTM with 4 Inputs
c. Factory Settings

Model	Heat-H "A"	Park "B"	Park "C"	Cool-H "D"
TUD1B080A9H31C	Blue/White	Yellow/White	Red/White	Black/White

d. Literature doesn't indicate anything regarding Constant Circulation
e. Airflow Table

FURNACE AIRFLOW (CFM) VS. STATIC PRESSURE (i.w.c.)										
Model	Speed Tap	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
TUD1B080A9H31C	4-High-Black/White	1328	1304	1277	1253	1224	1182	1127	1057	959
	3-Med.-High-Blue/White	1519	1493	1464	1422	1368	1306	1242	1161	1054
	2-Med.-Low-Yellow/White	1072	1039	1015	991	956	928	891	858	828
	1-Low-Red/White	810	782	759	729	703	668	643	612	582

f. Rise Range Table

CFM VS. TEMPERATURE RISE									
MODEL	CFM (CUBIC FEET PER MINUTE)								
	1000	1100	1200	1300	1400	1500	1600	1700	1800
TUD1B080A9H31C		64	59	54	50	47	44	41	

FER airflow selection:
Settings to be operated by Thermostat:

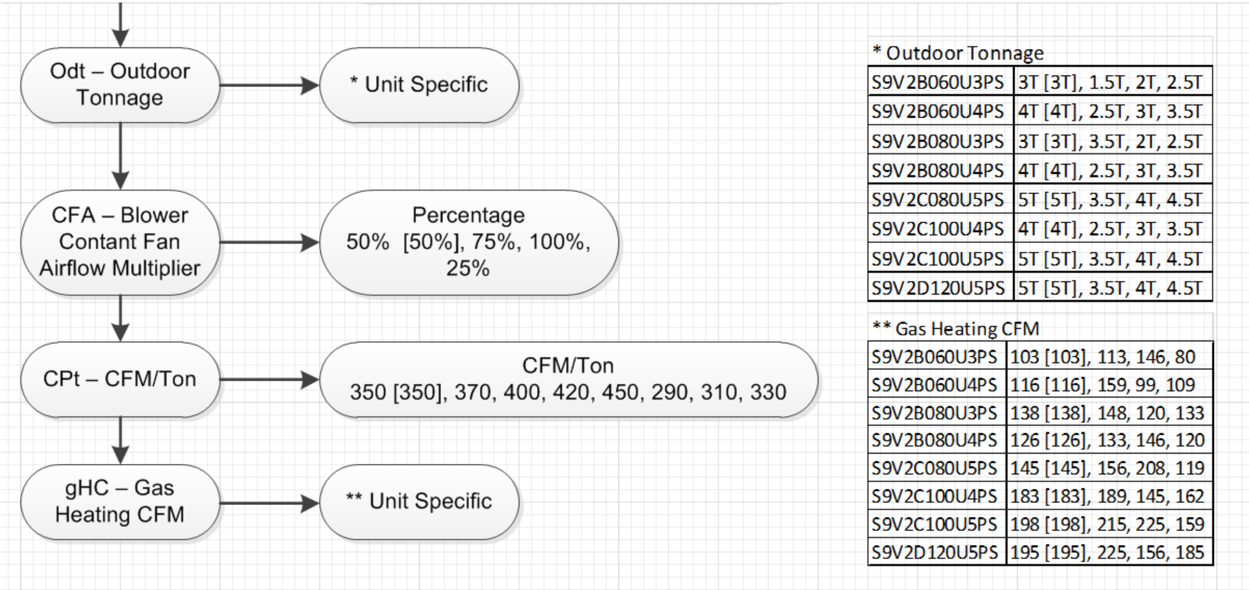
8.6.1 Max airflow control setting conducted in Heating Mode with Blue/White wire attached to Heat-H Tap.

8.6.2 Constant circulation airflow control conducted in Circ-Mode with Blue/White wire attached to Heat-H Tap.

8.6.3 Heating airflow control conducted in Heat Mode with Blue/White wire attached to Heat-H Tap.

Scenario 8. 2-Stage Heat, 2-Stage Cool

a. Control Configured by Menu/Option Buttons



* Outdoor Tonnage

S9V2B060U3PS	3T [3T], 1.5T, 2T, 2.5T
S9V2B060U4PS	4T [4T], 2.5T, 3T, 3.5T
S9V2B080U3PS	3T [3T], 3.5T, 2T, 2.5T
S9V2B080U4PS	4T [4T], 2.5T, 3T, 3.5T
S9V2C080U5PS	5T [5T], 3.5T, 4T, 4.5T
S9V2C100U4PS	4T [4T], 2.5T, 3T, 3.5T
S9V2C100U5PS	5T [5T], 3.5T, 4T, 4.5T
S9V2D120U5PS	5T [5T], 3.5T, 4T, 4.5T

** Gas Heating CFM

S9V2B060U3PS	103 [103], 113, 146, 80
S9V2B060U4PS	116 [116], 159, 99, 109
S9V2B080U3PS	138 [138], 148, 120, 133
S9V2B080U4PS	126 [126], 133, 146, 120
S9V2C080U5PS	145 [145], 156, 208, 119
S9V2C100U4PS	183 [183], 189, 145, 162
S9V2C100U5PS	198 [198], 215, 225, 159
S9V2D120U5PS	195 [195], 225, 156, 185

b. Motor configuration

   i. Variable Speed (ECM)

c. Factory Settings

Model	ODt	CFA	CPt	gHC
S9V2C100U4PS	4	50%	350	183

d. Literature doesn't indicate anything regarding Constant Circulation other than it's a Multiplication %

e. Heating Airflow Table (gHC)

S9V2C100U4PS Furnace Heating Airflow Table							
Heating	Airflow Setting	Target Airflow	External Static Pressure				
			0.1	0.3	0.5	0.7	0.9
Heating 1st Stage	Low	1146	1191	1199	1208	1216	1224
	Medium Low	1280	1314	1304	1294	1284	1274
	Medium Low	1446	1478	1466	1453	1441	1428
	High	1493	1498	1511	1524	1537	1550
Heating 2nd Stage	Low	1450	1480	1488	1496	1503	1511
	Medium Low	1620	1658	1656	1654	1652	1650
	Medium Low	1830	1869	1857	1846	1811	1714
	High	1890	1959	1919	1879	1811	1714

f. Cooling Airflow Table (ODt & CPt)

S9V2C100U4PS Furnace Cooling Airflow Table							
Odt - Unit Outdoor (ton)	CPt - Airflow Setting (CFM/ton)	Target Airflow	External Static Pressure				
			0.1	0.3	0.5	0.7	0.9
2.5	450	1125	1125	1125	1125	1125	1125
	400	1000	1000	1000	1000	1000	1000
	350	875	875	875	875	875	875
	290	725	725	725	725	725	725
4	450	1800	1800	1800	1800	1800	1714
	400	1600	1600	1600	1600	1600	1600
	350	1400	1400	1400	1400	1400	1400
	290	1160	1160	1160	1160	1160	1160

FER airflow selection:
Settings to be operated by Thermostat via Control Settings:

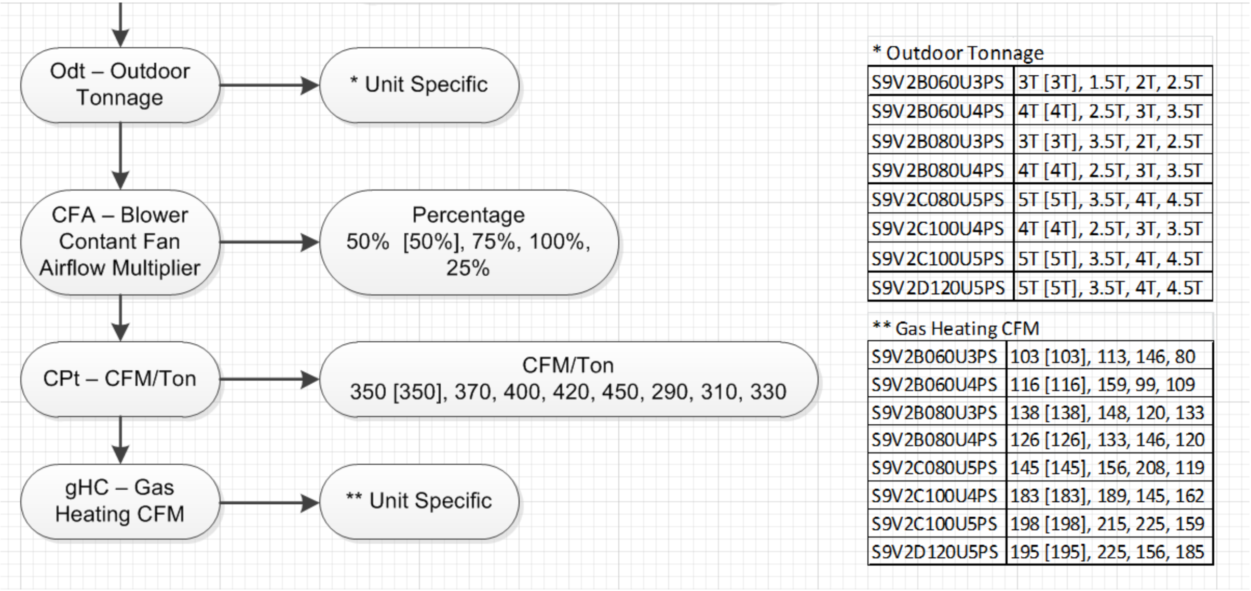
8.6.1 Max airflow control setting conducted in **Heat Mode** with gHC=1890.

8.6.2 Constant circulation airflow control conducted in Circ-Mode with ODt=4, CPt=450, and CFA=100%.

8.6.3 Heating airflow control conducted in Low Stage Heat Mode with gHC=1890.

Scenario 9. 2-Stage Heat, 2-Stage Cool

a. Control Configured by Menu/Option Buttons



* Outdoor Tonnage

S9V2B060U3PS	3T [3T], 1.5T, 2T, 2.5T
S9V2B060U4PS	4T [4T], 2.5T, 3T, 3.5T
S9V2B080U3PS	3T [3T], 3.5T, 2T, 2.5T
S9V2B080U4PS	4T [4T], 2.5T, 3T, 3.5T
S9V2C080U5PS	5T [5T], 3.5T, 4T, 4.5T
S9V2C100U4PS	4T [4T], 2.5T, 3T, 3.5T
S9V2C100U5PS	5T [5T], 3.5T, 4T, 4.5T
S9V2D120U5PS	5T [5T], 3.5T, 4T, 4.5T

** Gas Heating CFM

S9V2B060U3PS	103 [103], 113, 146, 80
S9V2B060U4PS	116 [116], 159, 99, 109
S9V2B080U3PS	138 [138], 148, 120, 133
S9V2B080U4PS	126 [126], 133, 146, 120
S9V2C080U5PS	145 [145], 156, 208, 119
S9V2C100U4PS	183 [183], 189, 145, 162
S9V2C100U5PS	198 [198], 215, 225, 159
S9V2D120U5PS	195 [195], 225, 156, 185

b. Motor configuration

   i. Variable Speed (ECM)

c. Factory Settings

Model	ODt	CFA	CPt	gHC
S9V2C100U4PS	4	50%	350	183

d. Literature doesn't indicate anything regarding Constant Circulation other than it's a Multiplication %

e. Heating Airflow Table (gHC)

S9V2C100U4PS Furnace Heating Airflow Table					
Heating	Airflow Setting	Target Airflow	External Static Pressure		
			0.1	0.3	0.5
Heating 1st Stage	Low	1146	1191	1199	1208
	Medium Low	1280	1314	1304	1294
	Medium Low	1446	1478	1466	1453
	High	1493	1498	1511	1524
Heating 2nd Stage	Low	1450	1480	1488	1496
	Medium Low	1620	1658	1656	1654
	Medium Low	1830	1869	1857	1846
	High	1890	1959	1919	1879

f. Cooling Airflow Table (ODt & CPt)

S9V2C100U4PS Furnace Cooling Airflow Table

Odt - Unit Outdoor (ton)	CPt - Airflow Setting (CFM/ton)	Target Airflow	External Static Pressure				
			0.1	0.3	0.5	0.7	0.9
2.5	450	1125	1125	1125	1125	1125	1125
	400	1000	1000	1000	1000	1000	1000
	350	875	875	875	875	875	875
	290	725	725	725	725	725	725
4	450	1800	1800	1800	1800	1800	1714
	400	1600	1600	1600	1600	1600	1600
	350	1400	1400	1400	1400	1400	1400
	290	1160	1160	1160	1160	1160	1160

FER airflow selection:
Settings to be operated by Thermostat via Control Settings:

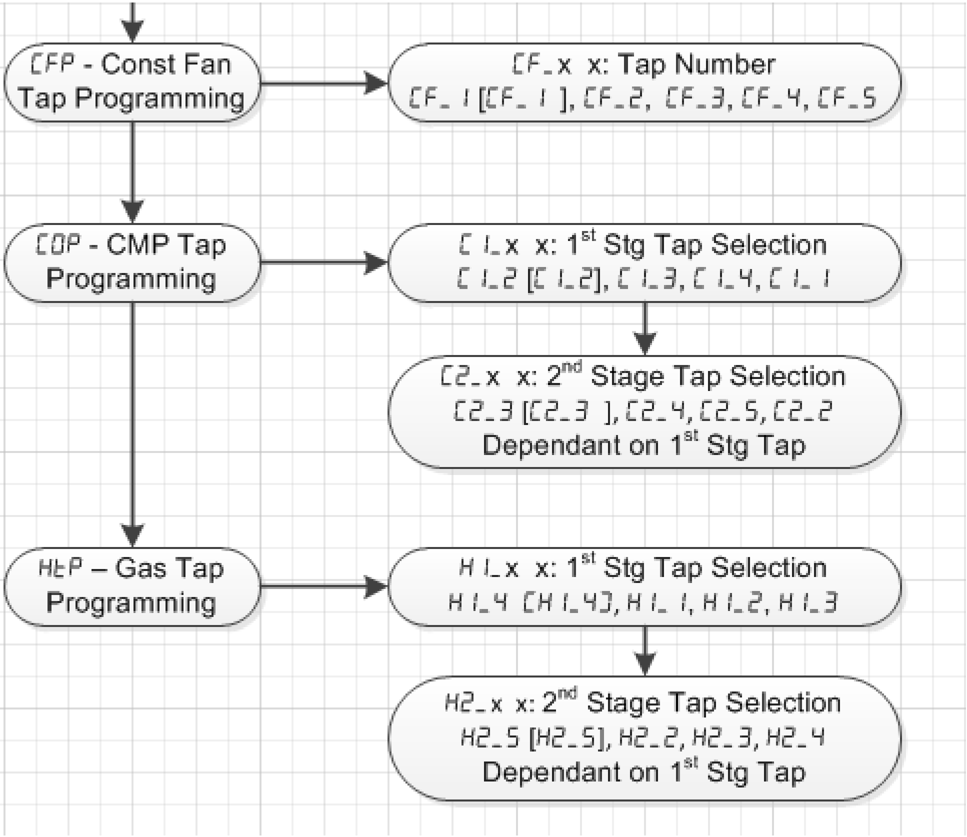
8.6.1 Max airflow control setting conducted in **Cooling Mode** with ODt=4 and CPt=450.

8.6.2 Constant circulation airflow control conducted in Circ-Mode with ODt=4, CPt=450, and CFA=100%.

8.6.3 Heating airflow control conducted in Low Stage Heat Mode with gHC=1890.

Scenario 10. 2-Stage Heat, 2-Stage Cool

a. Control Configured by Menu/Option Buttons



b. Motor configuration
    i. Constant Torque (CTM)

c. Factory Settings

Model	1st Stage Cooling	2nd Stage Cooling	Constant Fan	1st Stage Heating	2nd Stage Heating
S9V2C100U4PS	C1.2	C2.3	CF.1	H1.4	H2.5

d. Literature doesn't indicate anything regarding Constant Circulation other than five taps are available.

e. Airflow Table

FURNACE AIRFLOW (CFM) VS. STATIC PRESSURE (i.w.c.)										
Model	Speed Tap	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
S9X2B080U3PS	5 - HIGH	1603	1577	1552	1526	1499	1472	1444	1414	1379
	4 - MED-HIGH	1426	1399	1372	1344	1316	1283	1250	1214	1175
	3 - MEDIUM	1176	1144	1109	1074	1034	992	948	906	862
	2 - MED-LOW	1077	1027	990	950	905	856	807	763	714
	1 - LOW	1001	904	833	776	722	669	609	559	503

f. Rise Range Table

CFM VS. TEMPERATURE RISE										
	CFM (CUBIC FEET PER MINUTE)									
MODEL	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
S9X2B080U3PS		71	68	62	57	55	50	45	39	

FER airflow selection:
Settings to be operated by Thermostat via Control Settings:

8.6.1 Max airflow control setting conducted in Cooling Mode with C2.5 tap.
8.6.2 Constant circulation airflow control conducted in Circ-Mode with CF.5 tap.
8.6.3 Heating airflow control conducted in Heat Mode with H1.4 tap.

Scenario 11. The following airflow tables represent 2 examples of the same 3 ton packaged gas/electric unit with two available gas heating sizes: 50kBtuh and 85kBtuh. For the sake of commonality, the manufacturer uses the same blower system in both heating sizes. There are 5 blower speeds on the blower motor. The control is such that the same fan speed may not be used for more than 1 function.

TABLE 1: Dry Coil Air Delivery - Packaged Gas/Electric

Cooling Size Tons)	Heating Size (Btu/hr)	Heating Rise Range °F	Motor Speed		External Static Pressure ("WC)									
					Available Static Pressures for Cooling and Heating Modes					High Static Cooling Operation Only				
					0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
3 Ton	50K	35 - 65	Low[3]	CFM	650	600	550	500	450	400	350	300	250	361
				Heat Rise (°F)	58	62	NA	NA	NA	Not Allowed				
			Med-Low[1]	CFM	800	750	700	650	600	890	825	760	673	572
				Heat Rise (°F)	47	50	53	58	62	Not Allowed				
			Medium[2]	CFM	1275	1225	1175	1125	1075	1025	975	925	925	850
				Heat Rise (°F)	NA	NA	NA	NA	35	Not Allowed				
			Med-High	CFM	1320	1265	1200	1140	1090	1040	1025	958	889	822
				Heat Rise (°F)	NA	NA	NA	NA	NA	Not Allowed				
			High	CFM	1500	1450	1400	1350	1315	1275	1250	1225	1200	1175
				Heat Rise (°F)	NA	NA	NA	NA	NA	Not Allowed				
	85K	35 - 65	Low[3]	CFM	650	600	550	500	450	400	350	300	250	361
				Heat Rise (°F)	Not Allowed					Not Allowed				
			Med-Low	CFM	800	750	700	650	600	890	825	760	673	572
				Heat Rise (°F)	Not Allowed					Not Allowed				
			Medium[2]	CFM	1275	1225	1175	1125	1075	1025	975	925	925	850
				Heat Rise (°F)	50	52	54	57	59	Not Allowed				
			Med-High[1]	CFM	1320	1265	1200	1140	1090	1040	1025	958	889	822
				Heat Rise (°F)	48	50	53	56	58	Not Allowed				
			High	CFM	1500	1450	1400	1350	1315	1275	1250	1225	1200	1175
				Heat Rise (°F)	42	44	45	47	48	Not Allowed				

Notes:
"NA" = Not allowed for heating speed
1 = Factory-wired heating fan speed
2 = Factory-wire cooling fan speed
3 = Factory-wired constant circulation fan speed

For the Table 1 airflow:

85K model:

1. Cooling function must be run at the High speed for Qmax determination @ .5"wc ESP, per table II.1 of the FER Calculation Procedure. Test run according to Appendix AA 8.6.1.1.
2. Heating function must be run at the Med-High speed since the control system does not allow more than 1 function on the same speed (Appendix AA 2.2).

3. A continuous circulation function fan speed is not specified (although the manufacturer connects the lowest fan speed to constant circulation function as shipped). In this case, the lowest constant circulation function is run on Low fan speed (Appendix AA, 8.6.2).

50K Model:

1. Cooling function must be run at the High speed for Qmax determination@ .5”wc ESP, per table II.1 of the FER Calculation Procedure. Test run according to Appendix AA 8.6.1.1.
2. Heating function can’t be run at the High speed, since the control system does not allow more than 1 function on the same speed (Appendix AA 2.2). Heating can’t be run on the Med-High speed since, for the tested resultant static (.45”ESP), the speed is marked “NA” (Not allowed for heating fan speed). On Medium speed, the tested resultant static is .4”ESP, which indicates “NA” (Not allowed for heating fan speed). Heating is then determined by running on the Med-Low tap.
3. A continuous circulation function fan speed is not specified (although the manufacturer connects the lowest fan speed to constant circulation function as shipped). In this case, the constant circulation function is run on Low fan speed (Appendix AA, 8.6.2).

Table 2: Dry Coil Air Delivery - Packaged Gas/Electric

Cooling Size Tons)	Heating Size (Btu/hr)	Heating Rise Range °F	Function	Motor Speed		External Static Pressure ("WC)									
						Available Static Pressures for Cooling and Heating Modes					High Static Cooling Operation Only				
						0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
3	50K, 85K	35 - 65	Unspecified	Low[3]	CFM	650	600	550	500	450	400	350	300	250	361
			50K Heat	Med-Low[1]	CFM	800	750	700	650	600	890	825	760	673	572
			Cool	Medium[2]	CFM	1275	1225	1175	1125	1075	1025	975	925	925	850
			85K Heat	Med-High[1]	CFM	1320	1265	1200	1140	1090	1040	1025	958	889	822
			High Static Cool	High	CFM	1500	1450	1400	1350	1315	1275	1250	1225	1200	1175

Notes:
"NA" = Not allowed for heating speed
1 = Factory-wired heating fan speed
2 = Factory-wire cooling fan speed
3 = Factory-wired constant circulation fan speed

For the Table 2 airflow:

85K model:

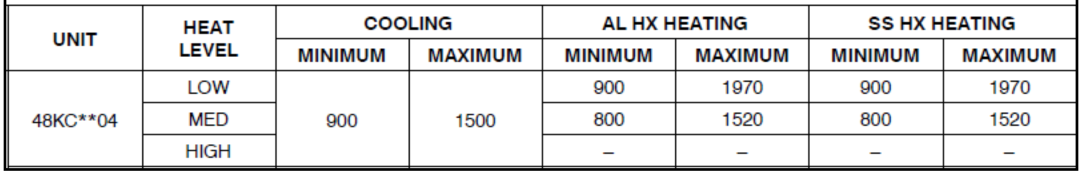
1. Cooling function must be run at the High speed for Qmax determination@ .5”wc ESP, per table II.1 of the FER Calculation Procedure. Test run according to 8.6.1.1.
2. Heating function must be run on the Med-High speed as specifically designated for 85K heating (Appendix AA 2.2).
3. Continuous circulation function fan speed is unspecified (Although the manufacturer connects the lowest fan speed to constant circulation function as shipped), so the function is run on Low fan speed (Appendix AA, 8.6.2).

50K Model:

1. Cooling function must be run at the High speed for Qmax determination@ .5”wc ESP, per table II.1 of the FER Calculation Procedure. Test run according to Appendix AA 8.6.1.1.
2. Heating function is run on Med-Low speed, since it is designated by the manufacturer as the specified speed for 50K heating (Appendix AA 2.2).
3. Continuous circulation function fan speed is unspecified (Although the manufacturer connects the lowest fan speed to constant circulation function as shipped), so the function is run on Low fan speed (Appendix AA, 8.6.2).

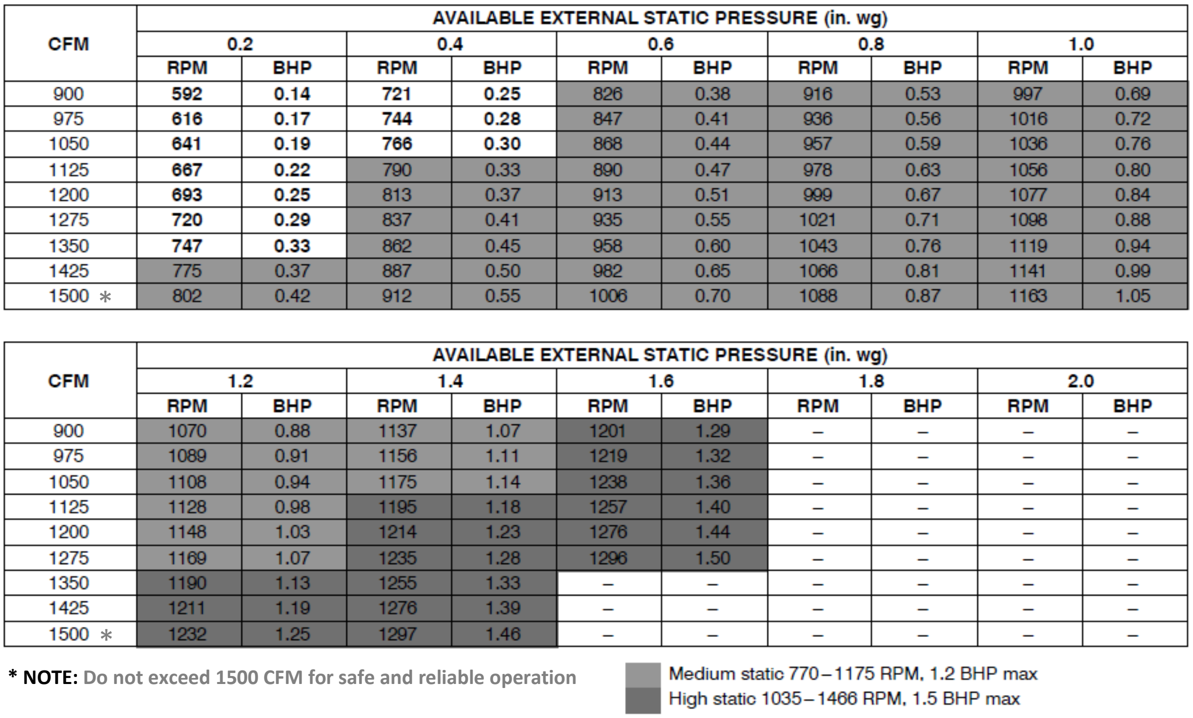
Scenario 12. Airflow for Packaged Equipment. There are single phase packaged weatherized products sold with belt drive fan systems that are designed to accommodate high static air distribution systems used in commercial applications. These units have no airflow-controls that would result in different fan speeds for cooling, heating, or constant circulation. They can be a manually adjusted by changing the motor pulley pitch diameter, which is performed at the time of installation. The installation instructions shipped with the unit warns the installer that for safe and reliable operation that they must ensure that the unit operates within the airflow limits as shown in the table below. The installers are licensed mechanical contractors who are knowledge about the correct installation procedures.

Minimum & Maximum allowable airflows



UNIT	HEAT LEVEL	COOLING		AL HX HEATING		SS HX HEATING	
		MINIMUM	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
48KC**04	LOW	900	1500	900	1970	900	1970
	MED			800	1520	800	1520
	HIGH			–	–	–	–

The table shown below is the installation literature for the supply fan operating performance for three motor/static options.



CFM	AVAILABLE EXTERNAL STATIC PRESSURE (in. wg)									
	0.2		0.4		0.6		0.8		1.0	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
900	**592**	**0.14**	**721**	**0.25**	826	0.38	916	0.53	997	0.69
975	**616**	**0.17**	**744**	**0.28**	847	0.41	936	0.56	1016	0.72
1050	**641**	**0.19**	**766**	**0.30**	868	0.44	957	0.59	1036	0.76
1125	**667**	**0.22**	790	0.33	890	0.47	978	0.63	1056	0.80
1200	**693**	**0.25**	813	0.37	913	0.51	999	0.67	1077	0.84
1275	**720**	**0.29**	837	0.41	935	0.55	1021	0.71	1098	0.88
1350	**747**	**0.33**	862	0.45	958	0.60	1043	0.76	1119	0.94
1425	775	0.37	887	0.50	982	0.65	1066	0.81	1141	0.99
1500 *	802	0.42	912	0.55	1006	0.70	1088	0.87	1163	1.05

CFM	AVAILABLE EXTERNAL STATIC PRESSURE (in. wg)									
	1.2		1.4		1.6		1.8		2.0	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
900	1070	0.88	1137	1.07	1201	1.29	–	–	–	–
975	1089	0.91	1156	1.11	1219	1.32	–	–	–	–
1050	1108	0.94	1175	1.14	1238	1.36	–	–	–	–
1125	1128	0.98	1195	1.18	1257	1.40	–	–	–	–
1200	1148	1.03	1214	1.23	1276	1.44	–	–	–	–
1275	1169	1.07	1235	1.28	1296	1.50	–	–	–	–
1350	1190	1.13	1255	1.33	–	–	–	–	–	–
1425	1211	1.19	1276	1.39	–	–	–	–	–	–
1500 *	1232	1.25	1297	1.46	–	–	–	–	–	–

*** NOTE:** Do not exceed 1500 CFM for safe and reliable operation

▨ Medium static 770–1175 RPM, 1.2 BHP max
■ High static 1035–1466 RPM, 1.5 BHP max

FER Airflow Selection:

The Qmax is 1500 CFM based upon the manufactures instructions supplied with the unit. EMax, Eheat & Ecir will all be run at 1500 CFM, which is achieved by manually adjusting the pulleys for a max speed of 959 RPM

Scenario 13. Unspecified tap, not specified in I/O what to use for constant circulation mode, but with a dedicated constant circulation mode speed on the control. Test procedure says to use lowest speed available when unspecified.

1. Control shipped with tap setting 4 of 5, but would 5 be used for FER?

   A 1-stage gas furnace with a 5 speed motor is manufactured and shipped with the Black (High) motor speed tap connected to the control relay that operates during Cooling mode. The Blue (Medium) motor speed tap is connected to the control relay that operates during Heating mode. The Yellow (Medium-Low) motor speed tap is connected to a dedicated terminal on the control for Constant Circulation mode. The other two motor speeds, Brown (Medium-High) and Red (Low) are connected to "Park" terminals on the control. The following sentence is the only information that is printed in the installation instruction that is supplied with the furnace about Constant Circulation mode:

   Indoor Blower Speeds
   1 – When the thermostat is set to "FAN ON" the indoor blower will run continuously on the fan speed (FAN) when there is no cooling or heating demand.

   The following blower table is printed in the installation instructions supplied with the furnace:

Speed Tap	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Black	1360	1310	1275	1250	1215	1200	1145	1110
Brown	1270	1250	1205	1175	1145	1100	1070	1035
Blue	1180	1130	1100	1065	1045	995	960	925
Yellow	915	880	835	795	745	705	670	610
Red	865	815	775	730	670	640	585	550

   <u>FER Interpretation</u>:

   Max airflow (Q_{Max}) and electrical consumption (E_{Max}) are determined using the Black (High) speed tap in Cooling mode with the ESP adjusted to 0.65-inWC.

   Heat airflow (Q_{Heat}) and heating electrical consumption (E_{Heat}) are determined using the Blue (Medium) speed tap at the resultant airflow and ESP. Q_{Max} is calculated based on the determination of Q_{Heat} from equations in the Appendix AA of Part 430 Subpart B.

   Constant circulating airflow electrical consumption (E_{Circ}) is determined to be lowest (Red) speed tap, because the manufacturer <u>did not</u> specify in their installation instructions a constant circulation airflow control setting.

2. If tap is specified, however, the highest specified tap will be used.

   A 2-stage gas furnace with a 5 speed motor is manufactured and shipped with the Black (High) motor speed tap connected to the control relay that operates during High Cooling mode. The Brown (Medium-High) motor speed tap is connected to the control relay that operates during High Heating mode. The Blue (Medium) motor speed tap is connected to the control relay that operates during Low Cooling mode. The Yellow (Medium-Low) motor speed tap is connected to the control relay that operates during Low Heating mode. The other motor speed, Red (Low), is connected to a "Park" terminal on the control. For Constant Circulation mode, there are two dip switches, switches 6 and 7, that are both factory set to OFF which sets the Constant Circulation speed to Yellow (Medium-Low) to be the same as Low Heating mode. The following sentences and table are the only information that is printed in the installation instruction that is supplied with the furnace about Constant Circulation mode:

> ***Indoor Blower Speeds***
>
> *1 – When the thermostat is set to "FAN ON" the indoor blower will run continuously on the field selectable fan speed ("LOW HEAT" is default) when there is no cooling or heating demand.*
>
> ***Switches 6 and 7 – Constant Circulation Mode*** *– Constant circulation speed can be controlled by changing DIP switch positions. Table 12 below provides DIP switch settings for constant circulation mode.*

TABLE 12
Constant Circulation Mode Settings

Constant Circulation Mode	Switch 6	Switch 7
Low Heat Speed (Factory)	OFF	OFF
Low Cool Speed	OFF	ON
High Heat Speed	ON	OFF
High Cool Speed	ON	ON

The following blower table is printed in the installation instructions supplied with the furnace:

Speed Tap	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Black	1360	1310	1275	1250	1215	1200	1145	1110
Brown	1270	1250	1205	1175	1145	1100	1070	1035
Blue	1180	1130	1100	1065	1045	995	960	925
Yellow	915	880	835	795	745	705	670	610
Red	865	815	775	730	670	640	585	550

FER Interpretation:

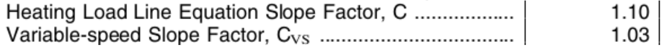
Max airflow (Q_{Max}) and electrical consumption (E_{Max}) are determined using the Black (High) speed tap in High Cooling mode with the ESP adjusted to 0.65-inWC.

Heat airflow (Q_{Heat}) and heating electrical consumption (E_{Heat}) are determined using the Yellow (Medium-Low) speed tap for Low Heat mode at the resultant airflow and ESP. Q_{Max} is calculated based on the determination of Q_{Heat} from equations in the Appendix AA of Part 430 Subpart B.

Constant circulating airflow electrical consumption (ECirc) is determined to be High (Black) speed tap, because the manufacturer did specify in their installation instructions that the dip switches 6 and 7 can both be set to ON for High Cool Speed in Table 12 for the constant circulation airflow control setting.

Exhibit 2

Table 1. List of Errors Found in Appendix M and M1

Section	M	M1	Original Language in Appendix M /M1	AHRI's Comment
1. Definition of 'Nominal Capacity'	X		*Nominal cooling capacity* is approximate to the air conditioner cooling capacity tested at A or A_2 condition. Nominal heating capacity is approximate to the heat pump heating capacity tested in $H1_2$ test (or the optional $H1_N$ test).	1. H1N is 'required' in the Section 3.6.4. 2. Nominal designates $H1_N$, not $H1_2$ in 3.6.4. To avoid confusion, only $H1_N$ should be retained in the Definition.
3.6.4	X		For a cooling/heating heat pump, the compressor shall operate for the $H1_N$ test at a speed, measured by RPM or power input frequency (Hz), no lower than the speed used in the A_2 test if the tested $H1_2$ heating capacity is less than the tested cooling capacity in A_2 test.	1. The language does not instruct what speed should be used *if* the following condition is *not* met '*...if the tested $H1_2$ heating capacity is less than the tested cooling capacity in A_2 test*'. In such case, it is desirable to set $H1_N$ speed same or equal to maximum compressor speed in cooling. 2. Update H1N definition from M to M1 language
4.1.4.2	X		$A = EER^{k=1}(T_2) - B * T_2 - C * T_2^2$	The $EER^{k=1}(T_2)$ should be $EER^{k=2}(T_2)$ because the coefficient A only utilizes maximum speed temperature, T_2.
4.2.c	X		c. For a variable-speed heat pump, $\dot{Q}_h^k(47) = \dot{Q}_h^{k=N}(47)$, the space heating capacity determined from the H1Ntest.	1. 2017 and later versions of Appendix M uses $H^{k=2}_{calc}$ for all calculations even if $H^{k=2}_{calc} = H1_N$ instead of $H1_N$ as explained in 3.6.4. This should not be an exception for the rest of calculation process in Appendix M. 2. Language is ambiguous
4.2		X	$\dot{Q}_h(47°F)$: the heating capacity at 47 °F determined from the H_2 $H1_2$ or $H1_N$ test, Btu/h.	1. For variable speed heat pumps, the language should be clarified to use $H^{k=2}_{calc}$. (For the same reason above) 2. Language is ambiguous for variable-speed heat pumps.
4.2		X	Table 20—Generalized Climatic Region Information  Heating Load Line Equation Slope Factor, C .... 1.10 Variable-speed Slope Factor, C_{VS} .... 1.03 Equation 4.2-2	Table 20 in Appendix M1 has two different slope factors, C (for non-variable-speed) and C_{vs} (for variable-speed. However, the building load calculation equation, Equation 4.2-2, does not direct to use the '2. 1. Variable-speed Slope Factor, C_{vs}, instead of C for variable-speed heat pumps.

			Equation 4.2-2 $BL(T_j) = \frac{(T_{zl}-T_j)}{T_{zl}-5°F} * C * \dot{Q}_c(95°F)$ C = the slope (adjustment) factor, which varies by climate region according to Table 20	2. Separate into two different equations or add sentence (where C_{vs} exists, use C_{vs}) to determine whether to use C factor or C_{vs}
4.2.3.1	X	X	$\delta'(T_j)$ = the low temperature cutoff factor, dimensionless.	$\delta'(T_j)$ should be $\delta(T_j)$ because $\delta'(T_j)$ does not exist in 4.2.3.1. This should match exactly because other subsections use $\delta'(T_j)$ with different formulations based on different operational schema.
4.2.3.3	X	X	$PLF_j = 1 - C_D{}^h(k = 2) * [1 - X^{k=1}(T_j)$	Trailing square bracket ‘]’ should be added. $X^{k=1}(T_j)$ should be $X^{k=2}(T_j)$ because the governing control scheme in 4.2.3.3 is the high capacity mode only.
4.2.3.4	X	X	$\frac{RH(T_j)}{N} = \frac{BL(T_j)*[\dot{Q}_h^{k=2}(T_j)*\delta'(T_j)]}{3.413\frac{Btu/h}{W}} * \frac{n_j}{N}$	The multiplication ‘*’ between BL(Tj) and the square bracket should be minus ‘-’ because RH is a function of a difference between building load (demand) and heating capacity of a heat pump (supply).
4.2.6.7	X	X	Calculate δ″(Tj) using the equation given in section 4.2.3.4 of this appendix.	4.2.3.4 does not use δ″(Tj). Only δ'(Tj) is used.
4.2.6.8	X	X	$\frac{e_h(T_j)}{N} = \dot{E}_h^{k=3}(T_j) * \delta'(T_j) * \frac{n_j}{N}$ and $\frac{RH(T_j)}{N} = \frac{BL(T_j)-[\dot{Q}_h^{k=3}(T_j)*\delta'(T_j)]}{3.413\frac{Btu/h}{W}} * \frac{n_j}{N}$ where $\delta''(T_j)$ is calculated as specified in section 4.2.3.4	$\delta''(T_j)$ should be $\delta'(T_j)$. 4.2.3.4 does not have $\delta''(T_j)$ but $\delta'(T_j)$.

How the current calculation is written.

$$\eta_r = \left(\frac{M_1 * C_{p1} * \left(\overline{T}_{del,1} - \overline{T}_{in,1}\right)}{Q_r} + \frac{V_{st} * \rho_2 * C_{p2}\left(\overline{T}_{max,1} - \overline{T}_0\right)}{Q_r}\right)$$

Where this calculation falls short is when our first cut-out occurs into or through subsequent draws. The definition of $\overline{T}_{del,1}$ and $\overline{T}_{in,1}$ are currently defined as the "average water temperature measured during the Draws from the start of the 24 hour simulated-use test to the end of the first recovery period,°F,(°C)."

Our Proposal:

We would like to propose the calculation below to avoid inflating the energy delivered that the averaging causes.

$$\eta_r = \sum_{i=1}^{N_r} \frac{m_i * C_{pi} * \left(\overline{T}_{del,i} - \overline{T}_{in,i}\right)}{Q_r} + \frac{V_{\mathrm{st}}\rho_2 C_{p2}\left(\overline{T}_{\mathrm{max},1} - \overline{T}_0\right)}{Q_r}$$

$\boldsymbol{N_r}$ = number of draws that the first recovery period occurred during.

First Recovery Period: is defined by when the main burner of a storage water heater is lit and raising the temperature of the stored water until cut-out; in the case the cut-out* occurs during a subsequent draw, the first recovery period is to include the time until the draw of water from the tank stops.

$\boldsymbol{m_i}$ = Mass of draw i.

$\boldsymbol{C_{pi}}$ = Average Specific heat of draw i.

$\boldsymbol{Q_r}$ = Energy consumption of water heater from the beginning of the test to the end of the first recovery period

For example, if $\boldsymbol{N_r = 2}$

$$\eta_r = \left(\frac{mass_1 * C_{p1} * \left(\overline{T}_{del,1} - \overline{T}_{in,1}\right)}{Q_r} + \frac{mass_2 * C_{p2} * \left(\overline{T}_{del,2} - \overline{T}_{in,2}\right)}{Q_r} + \frac{V_{st} * \rho_2 * C_{p2}\left(\overline{T}_{max,1} - \overline{T}_0\right)}{Q_r}\right)$$

*If after the first cut-out occurs during a subsequent draw, a subsequent cut-in occurs prior to the draw completion, the first recovery period is to include the time until the subsequent cut-out occurs, prior to another draw.

Appendix A to Subpart G of Part 431—Uniform Test Method for the Measurement of Thermal Efficiency and Standby Loss of Gas-Fired and Oil-Fired Storage Water Heaters and Storage-Type Instantaneous Water Heaters

{…}

TABLE 3.2—DATA TO BE RECORDED BEFORE AND DURING THE STANDBY LOSS TEST

Item recorded	Before test	Every 1 minute[a]
Gas supply pressure, in w.c.	X	
Gas outlet pressure, in w.c.	X	
Barometric pressure, in Hg	X	
Fuel higher heating value, Btu/ft^3 (gas) or Btu/lb (oil)	X	
Oil pump pressure, psig (oil only)	X	
CO_2 reading, % (oil only)	X[b]	
Oil smoke spot reading (oil only)	X[b]	
Air draft, ft/min	X	
Time, minutes/seconds		X
Mean tank temperature, °F		X[c]
Ambient room temperature, °F		X
Test air temperature, °F		X

Notes:

[a] These measurements are to be recorded at the start and end of the test, as well as every minute during the test.

[b] The smoke spot test and CO_2 reading are not required prior to beginning the standby loss test if no settings on the water heater have been changed and the water heater has not been turned off since the end of a previously-run efficiency test (*i.e.,* thermal efficiency or standby loss).

[c] Mean tank temperature is calculated as the average of the 6 tank temperature sensors, installed per section 2.3 of this appendix.

4. Determination of Storage Volume. Determine the storage volume by subtracting the tare weight, measured while the system is dry and empty, from the weight of the system when filled with water and dividing the resulting net weight of water by the density of water at the measured water temperature. The volume of the water contained in the water heater must be computed in gallons.

5. *Thermal Efficiency Test.* Before beginning the steady-state verification period, record the applicable parameters as specified in section 3.8.2 of this appendix. Begin drawing water from the unit by opening the main supply, and adjust the water flow rate to achieve an outlet water temperature of 70 °F ±

2 °F above supply water temperature. The thermal efficiency test shall be deemed complete when there is a continuous, one-hour-long period where the steady-state conditions specified in section 5.1 of this appendix have been met~~, as confirmed by consecutive readings of the relevant parameters recorded at 1-minute intervals (except for fuel input rate, which is determined at 10-minute intervals, as specified in section 5.4 of this appendix)~~. During the one-hour-long period, the water heater must fire continuously at its full firing rate (*i.e.,* no modulations or cut-outs) and no settings can be changed on the unit being tested at any time. The first 30 minutes of the one-hour-period where the steady-state conditions in section 5.1 of this appendix are met is the steady-state verification period. The final 30 minutes of the one-hour-period where the steady-state conditions in section 5.1 of this appendix are met is the thermal efficiency test. The last reading of the steady-state verification period must be the first reading of the thermal efficiency test (*i.e.,* the thermal efficiency test starts immediately once the steady-state verification period ends).

5.1. *Steady-State Conditions.* The following conditions must be met ~~at consecutive readings taken at 1-minute intervals (except for fuel input rate, for which measurements are taken at 10-minute intervals)~~ to verify the water heater has achieved steady-state operation during the steady-state verification period and thermal efficiency test.

5.1.1. The water flow rate must be maintained within ± 0.25 gallons per minute (gpm) of the average flowrate during the steady-state verification period and thermal efficiency test, or 4% of the average flowrate, whichever is greater.~~The water flow rate must be maintained within ± 0.25 gallons per minute (gpm) of the initial reading at the start of the steady-state verification period;~~

5.1.2. The average outlet water temperature must be maintained at 70 °F ± 2 °F above the average supply water temperature during the steady state verification period and the thermal efficiency test.~~Outlet water temperature must be maintained at 70 °F ± 2 °F above supply water temperature;~~

5.1.3. Fuel input rate must be maintained within ± 2 percent of the rated input certified by the manufacturer.~~;~~

5.1.4. The average supply water temperature (T_{SWT}) during the steady-state verification period and the thermal efficiency test must be within 70 °F ± 1.00 °F.~~The supply water temperature must be maintained within ± 0.50 °F of the initial reading at the start of the steady-state verification period; and~~

5.1.5. The rise between average supply (or inlet if a recirculating loop is used) and outlet water temperatures must be maintained within ± 1.00 °F of its initial value taken at the start of the steady-state verification period.~~The rise between the supply and outlet water temperatures must be maintained within ± 0.50 °F of its initial value taken at the start of the steady-state verification period for units with rated input less than 500,000 Btu/h, and maintained within ± 1.00 °F of its initial value for units with rated input greater than or equal to 500,000 Btu/h.~~

5.2. *Water Flow Measurement.* Measure the total weight of water heated during the 30-minute thermal efficiency test with either a scale or a water flow meter. With either method, the error of measurement of weight of water heated must not exceed 1 percent of the weight of the total draw.

5.3. *Determination of Fuel Input Rate.* During the steady-state verification period and the thermal efficiency test, record the fuel consumed at 10-minute intervals. Calculate the fuel input rate over each 10-minute period using the equations in section 5.4 of this appendix. The measured fuel input rates for these 10-minute periods must not vary by more than ± 2 percent between any two readings. Determine the overall fuel input rate using the fuel consumption for the entire duration of the thermal efficiency test.

5.4. *Fuel Input Rate Calculation.* To calculate the fuel input rate, use the following equation:

$$Q = \frac{Q_s * C_s * H}{t}$$

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Where,

Q = Fuel input rate, expressed in Btu/h

Q_s = Total fuel flow as metered, expressed in ft^3 for gas-fired equipment and lb for oil-fired equipment

C_s = Correction applied to the heating value of a gas H, when it is metered at temperature and/or pressure conditions other than the standard conditions for which the value of H is based. Cs=1 for oil-fired equipment.

H = Higher heating value of fuel, expressed in Btu/ft^3 for gas-fired equipment and Btu/lb for oil-fired equipment.

t = Duration of measurement of fuel consumption

5.5. *Thermal Efficiency Calculation.* Thermal efficiency must be calculated using data from the 30-minute thermal efficiency test. Calculate thermal efficiency, E_t, using the following equation:

$$E_t = \frac{K * W * (\theta_2 - \theta_1)}{(C_s * Q * H) + E_c}$$

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Where,

K = 1.004 Btu/lb· °F, the nominal specific heat of water at 105 °F

W = Total weight of water heated, expressed in lb

θ_1 = Average supply water temperature, expressed in °F

θ_2 = Average outlet water temperature, expressed in °F

Q = Total fuel flow as metered, expressed in ft^3 for gas-fired equipment and lb for oil-fired equipment.

C_s = Correction applied to the heating value of a gas H, when it is metered at temperature and/or pressure conditions other than the standard conditions for which the value of H is based. C_s=1 for oil-fired equipment

H. = Higher heating value of the fuel, expressed in Btu/ft^3 for gas-fired equipment and Btu/lb for oil-fired equipment.

E_c = Electrical consumption of the water heater and, when used, the test set-up recirculating pump, expressed in Btu

6. Standby Loss Test

6.1. If no settings on the water heater have changed and the water heater has not been turned off since a previously run thermal efficiency or standby loss test, skip to section 6.3 of this appendix. Otherwise, conduct the soak-in period according to section 6.2 of this appendix.

6.2. *Soak-In Period.* Conduct a soak-in period, in which the water heater must sit without any draws taking place for at least 12 hours. Begin the soak-in period after setting the tank thermostat as specified in section 3.6 of this appendix, and maintain these thermostat settings throughout the soak-in period.

6.3. Begin the standby loss test at the first cut-out following the end of the soak-in period (if applicable); or at a cut-out following the previous thermal efficiency or standby loss test (if applicable). Allow the water heater to remain in standby mode. Do not change any settings on the water heater at any point until measurements for the standby loss test are finished. Begin recording the applicable parameters specified in section 3.8.3 of this appendix.

6.4. At the second cut-out, record the time and ambient room temperature, and begin measuring the fuel and electricity consumption. Record the initial mean tank temperature and initial ambient room temperature. For the remainder of the test, continue recording the applicable parameters specified in section 3.8.3 of this appendix.

6.5. Stop the test after the first cut-out that occurs after 24 hours, or at 48 hours, whichever comes first.

6.6. Immediately after conclusion of the standby loss test, record the total fuel flow and electrical energy consumption, the final ambient room temperature, the duration of the standby loss test, and if the test ends at 48 hours without a cut-out, the final mean tank temperature, or if the test ends after a cut-out, the maximum mean tank temperature that occurs after the cut-out. Calculate the average of the recorded values of the mean tank temperature and of the ambient room temperature taken at each measurement interval, including the initial and final values.

6.7. *Standby Loss Calculation.* To calculate the standby loss, follow the steps below:

6.7.1. The standby loss expressed as a percentage (per hour) of the heat content of the stored water above room temperature must be calculated using the following equation:

$$S = \frac{E_c + (C_s)(Q_s)(H) - \left(\frac{k(V_a)(\Delta T_4)}{E_t/100}\right)}{k(V_a)(\Delta T_3)(t)} \times 100$$

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Where,

ΔT_3 = Average value of the mean tank temperature minus the average value of the ambient room temperature, expressed in °F

ΔT_4 = Final mean tank temperature measured at the end of the test minus the initial mean tank temperature measured at the start of the test , expressed in °F

k = 8.25 Btu/gallon· °F, the nominal specific heat of water

V_a = Volume of water contained in the water heater in gallons measured in accordance with section 4 of this appendix

E_t = Thermal efficiency of the water heater determined in accordance with this appendix, expressed in %

E_c = Electrical energy consumed by the water heater during the duration of the test in Btu

t = Total duration of the test in hours

C_s = Correction applied to the heating value of a gas H, when it is metered at temperature and/or pressure conditions other than the standard conditions for which the value of H is based. C_s=1 for oil-fired equipment.

Q_s = Total fuel flow as metered, expressed in ft^3 (gas) or lb (oil)

H = Higher heating value of fuel, expressed in Btu/ft^3 (gas) or Btu/lb (oil)

S = Standby loss, the average hourly energy required to maintain the stored water temperature expressed as a percentage of the heat content of the stored water above room temperature

6.7.2. The standby loss expressed in Btu per hour must be calculated as follows:

SL (Btu per hour) = S (% per hour) × 8.25 (Btu/gal- °F) × Measured Volume (gal) × 70 (°F).

Where, SL refers to the standby loss of the water heater, defined as the amount of energy required to maintain the stored water temperature expressed in Btu per hour

[81 FR 79323, Nov. 10, 2016]

Back to Top

Appendix C to Subpart G of Part 431—Uniform Test Method for the Measurement of Thermal Efficiency and Standby Loss of Gas-Fired and Oil-Fired Instantaneous Water Heaters and Hot Water Supply Boilers (Other Than Storage-Type Instantaneous Water Heaters)

{…}

TABLE 3.2—DATA TO BE RECORDED BEFORE AND DURING THE STANDBY LOSS TEST

Item recorded	**Before test**	**Every 1 minute**[a]
Gas supply pressure, in w.c.	X	
Gas outlet pressure, in w.c.	X	
Barometric pressure, in Hg	X	
Fuel higher heating value, Btu/ft^3 (gas) or Btu/lb (oil)	X	
Oil pump pressure, psig (oil only)	X	
Air draft, ft/min	X	
Time, minutes/seconds		X
Heat exchanger outlet water temperature (T_{OHX}), °F		X
Ambient room temperature, °F		X
Test air temperature, °F		X
Water flow rate, gpm	X[b]	
Inlet water temperature (T_{IWT}), °F	X[b]	

Notes:

[a] These measurements are to be recorded at the start and end of the test, as well as every minute during the test.

[b] The water flow rate and supply water temperature and inlet water temperature (if a recirculating loop is used) must be measured during the steady-state verification period at 1-minute intervals. After the steady-state verification period ends, flow rate, supply water temperature, and inlet water temperature (if measured) are not required to be measured during the standby loss test, as there is no flow occurring during the standby loss test.

4. Determination of Storage Volume. Determine the storage volume by subtracting the tare weight, measured while the system is dry and empty, from the weight of the system when filled with water and dividing the resulting net weight of water by the density of water at the measured water temperature. The volume of water contained in the water heater must be computed in gallons.

5. Fuel Input Rate

5.1. Determination of Fuel Input Rate. During the steady-state verification period and thermal efficiency test, as applicable, record the fuel consumption at 10-minute intervals. Calculate the fuel input rate for each 10-minute period using the equations in section 5.2 of this appendix. The measured fuel input rates for these 10-minute periods must not vary by more than ± 2 percent between any two readings. Determine the overall fuel input rate using the fuel consumption for the entire duration of the thermal efficiency test.

5.2. Fuel Input Rate Calculation. To calculate the fuel input rate, use the following equation:

$$Q = \frac{Q_s * C_s * H}{t}$$

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Where:

Q = Fuel input rate, expressed in Btu/h

Q_s = Total fuel flow as metered, expressed in ft^3 for gas-fired equipment and lb for oil-fired equipment

C_s = Correction applied to the heating value of a gas H, when it is metered at temperature and/or pressure conditions other than the standard conditions for which the value of H is based. C_s=1 for oil-fired equipment.

H = Higher heating value of the fuel, expressed as Btu/ft^3 for gas-fired equipment and Btu/lb for oil-fired equipment.

t = Duration of measurement of fuel consumption

6. *Thermal Efficiency Test.* Before beginning the steady-state verification period, record the applicable parameters as specified in section 3.9.1 of this appendix. Begin drawing water from the unit by opening the main supply and outlet water valve, and adjust the water flow rate to achieve an outlet water temperature of 70 °F ± 2 °F above supply water temperature. The thermal efficiency test shall be deemed complete when there is a continuous, one-hour-long period where the steady-state conditions specified in section 6.1 of this appendix have been met~~, as confirmed by consecutive readings of the relevant parameters at 1-minute intervals (except for fuel input rate, which is determined at 10-minute intervals, as specified in section 5.1 of this appendix)~~. During the one-hour-long period, the water heater must fire continuously at its full firing rate (*i.e.,* no modulation or cut-outs) and no settings can be changed on the unit being tested at any time. The first 30 minutes of the one-hour-period where the steady-state conditions in section 6.1 of this appendix are met is the steady-state verification period. The final 30 minutes of the one-hour-period where the steady-state conditions in section 6.1 of this appendix are met is the thermal efficiency test. The last reading of the steady-state verification period must be the first reading of the thermal efficiency test (*i.e.,* the thermal efficiency test starts immediately once the steady-state verification period ends).

6.1. *Steady-State Conditions.* The following conditions must be met ~~at consecutive readings taken at 1-minute intervals (except for fuel input rate, for which measurements are taken at 10-minute intervals)~~ to verify the water heater has achieved steady-state operation during the steady-state verification period and the thermal efficiency test.

6.1.1. The water flow rate must be maintained within ± 0.25 gallons per minute (gpm) of the average flowrate ~~initial reading at the start of~~ during the steady-state verification period and thermal efficiency test, or 4% of the average flowrate, whichever is greater.

6.1.2. The average ~~O~~outlet water temperature must be maintained at 70 °F ± 2 °F above the average supply water temperature during the steady state verification period and the thermal efficiency test.

6.1.3. Fuel input rate must be maintained within ± 2 percent of the rated input certified by the manufacturer.

6.1.4. The average supply water temperature (T_{SWT}) ~~(or inlet water temperature (T_{IWT}) if a recirculating loop is used)~~ during the steady-state verification period and the thermal efficiency test must be ~~maintained~~ within 70 °F ± ~~0.50~~ 1.00 °F. ~~of the initial reading at the start of the steady-state verification period.~~

6.1.5. The rise between average supply (or inlet if a recirculating loop is used) and outlet water temperatures must be maintained within ± ~~0.50~~1.00 °F of its initial value taken at the start of the steady-state verification period. ~~for units with rated input less than 500,000 Btu/h, and maintained within ± 1.00 °F of its initial value for units with rated input greater than or equal to 500,000 Btu/h.~~

6.2. *Water Flow Measurement.* Measure the total weight of water heated during the 30-minute thermal efficiency test with either a scale or a water flow meter. With either method, the error of measurement of weight of water heated must not exceed 1 percent of the weight of the total draw.

6.3. *Thermal Efficiency Calculation.* Thermal efficiency must be calculated using data from the 30-minute thermal efficiency test. Calculate thermal efficiency, E_t, using the following equation:

$$E_t = \frac{K * W * (\theta_2 - \theta_1)}{(C_s * Q * H) + E_c}$$

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Where:

K = 1.004 Btu/lb· °F, the nominal specific heat of water at 105 °F

W = Total weight of water heated, lb

θ_1 = Average supply water temperature, expressed in °F

θ_2 = Average outlet water temperature, expressed in °F

Q = Total fuel flow as metered, expressed in ft^3 (gas) or lb (oil)

C_s = Correction applied to the heating value of a gas H, when it is metered at temperature and/or pressure conditions other than the standard conditions for which the value of H is based. C_s=1 for oil-fired equipment.

H = Higher heating value of the fuel, expressed in Btu/ft^3 (gas) or Btu/lb (oil)

E_c = Electrical consumption of the water heater and, when used, the test set-up recirculating pump, expressed in Btu

7. *Standby Loss Test.* If the standby loss test is conducted immediately after a thermal efficiency test and no settings or conditions have been changed since the completion of the thermal efficiency test, then skip to section 7.2 or 7.3 of this appendix (as applicable). Otherwise, perform the steady-state verification in section 7.1 of this appendix. For thermostatically-activated instantaneous water heaters with an internal thermostat, use section 7.2 of this appendix to conduct the standby loss test, and for flow-

activated and/or thermostatically-activated instantaneous water heaters with an external thermostat use section 7.3 of this appendix to conduct the standby loss test.

7.1. *Steady-State Verification Period.* For water heaters where the standby loss test is not conducted immediately following the thermal efficiency test, the steady-state verification period must be conducted before starting the standby loss test. Set the primary control in accordance with section 3.6 of this appendix, such that the primary control is always calling for heat and the water heater is firing continuously at the full firing rate (*i.e.,* no modulation or cut-outs). Begin drawing water from the unit by opening the main supply and the outlet water valve, and adjust the water flow rate to achieve an outlet water temperature of 70 °F ± 2 °F above supply water temperature. The steady-state verification period is complete when there is a continuous 30-minute period where the steady-state conditions specified in section 7.1.1 of this appendix are met, as confirmed by consecutive readings of the relevant parameters recorded at 1-minute intervals (except for fuel input rate, which is determined at 10-minute intervals, as specified in section 5.1 of this appendix).

7.1.1. *Steady-State Conditions.* The following conditions must be met at consecutive readings taken at 1-minute intervals (except for fuel input rate, for which measurements are taken at 10-minute intervals) to verify the water heater has achieved steady-state operation during the steady-state verification period prior to conducting the standby loss test.

7.1.1.1. The water flow rate must be maintained within ± 0.25 gallons per minute (gpm) of the initial reading at the start of the steady-state verification period;

7.1.1.2. Fuel input rate must be maintained within ± 2 percent of the rated input certified by the manufacturer;

7.1.1.3. The supply water temperature (T_{SWT}) (or inlet water temperature (T_{IWT}) if a recirculating loop is used) must be maintained within ± 0.50 °F of the initial reading at the start of the steady-state verification period; and

7.1.1.4. The rise between the supply (or inlet if a recirculating loop is used) and outlet water temperatures must be maintained within ± 0.50 °F of its initial value taken at the start of the steady-state verification period for units with rated input less than 500,000 Btu/h, and maintained within ± 1.00 °F of its initial value for units with rated input greater than or equal to 500,000 Btu/h.

7.2. *Thermostatically-Activated Instantaneous Water Heaters with an Internal Thermostat.* For water heaters that will experience cut-in based on a temperature-activated control that is internal to the water heater, use the following steps to conduct the standby loss test.

7.2.1. Immediately after the thermal efficiency test or the steady-state verification period (as applicable), turn off the outlet water valve(s) (installed as per the provisions in section 2.2 of this appendix), and the water pump (if applicable) simultaneously and ensure that there is no flow of water through the water heater.

7.2.2. After the first cut-out following the end of the thermal efficiency test or steady-state verification period (as applicable), allow the water heater to remain in standby mode. Do not change any settings on the water heater at any point until measurements for the standby loss test are finished. Begin recording the applicable parameters specified in section 3.9.2 of this appendix.

7.2.3. At the second cut-out, record the time and ambient room temperature, and begin measuring the fuel and electricity consumption. Record the initial heat exchanger outlet water temperature (T_{OHX}) and initial ambient room temperature. For the remainder of the test, continue recording the applicable parameters specified in section 3.9.2 of this appendix.

7.2.4. Stop the test after the first cut-out that occurs after 24 hours, or at 48 hours, whichever comes first.

7.2.5. Immediately after conclusion of the standby loss test, record the total fuel flow and electrical energy consumption, the final ambient room temperature, the duration of the standby loss test, and if the test ends at 48 hours without a cut-out, the final heat exchanger outlet temperature, or if the test ends after a cut-out, the maximum heat exchanger outlet temperature that occurs after the cut-out. Calculate the average of the recorded values of the heat exchanger outlet water temperature and the ambient room temperature taken at each measurement interval, including the initial and final values.

7.2.6. *Standby Loss Calculation.* To calculate the standby loss, follow the steps below:

7.2.6.1. The standby loss expressed as a percentage (per hour) of the heat content of the stored water above room temperature must be calculated using the following equation:

$$S = \frac{E_c + (C_s)(Q_s)(H) - \left(\frac{k(V_a)(\Delta T_4)}{E_t/100}\right)}{k(V_a)(\Delta T_3)(t)} \times 100$$

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Where:

ΔT_3 = Average value of the heat exchanger outlet water temperature (T_{OHX}) minus the average value of the ambient room temperature, expressed in °F

ΔT_4 = Final heat exchanger outlet water temperature (T_{OHX}) measured at the end of the test minus the initial heat exchanger outlet water temperature (T_{OHX}) measured at the start of the test, expressed in °F

K = 8.25 Btu/gallon· °F, the nominal specific heat of water

V_a = Volume of water contained in the water heater in gallons measured in accordance with section 4 of this appendix

E_t = Thermal efficiency of the water heater determined in accordance with section 6 of this appendix, expressed in %

E_c = Electrical energy consumed by the water heater during the duration of the test in Btu

T = Total duration of the test in hours

C_s = Correction applied to the heating value of a gas H, when it is metered at temperature and/or pressure conditions other than the standard conditions for which the value of H is based. C_s=1 for oil-fired equipment.

Q_s = Total fuel flow as metered, expressed in ft^3 (gas) or lb (oil)

H = Higher heating value of gas or oil, expressed in Btu/ft^3 (gas) or Btu/lb (oil)

S = Standby loss, the average hourly energy required to maintain the stored water temperature expressed as a percentage of the initial heat content of the stored water above room temperature

7.2.6.2. The standby loss expressed in Btu per hour must be calculated as follows:

SL (Btu per hour) = S (% per hour) × 8.25 (Btu/gal- °F) × Measured Volume (gal) × 70 (°F).

Where, SL refers to the standby loss of the water heater, defined as the amount of energy required to maintain the stored water temperature expressed in Btu per hour.

7.3. *Flow-Activated and Thermostatically-Activated Instantaneous Water Heaters with an External Thermostat.* For water heaters that are either flow-activated or thermostatically-activated with an external thermostat, use the following steps to conduct the standby loss test.

7.3.1. Immediately after the thermal efficiency test or the steady-state verification period (as applicable), de-energize the primary control to end the call for heating. If the main burners do not cut out, then turn off the fuel supply.

7.3.1.1. If the unit does not have an integral pump purge functionality, then turn off the outlet water valve and water pump at this time.

7.3.1.2. If the unit has an integral pump purge functionality, allow the pump purge operation to continue. After the pump purge operation is complete, immediately turn off the outlet water valve and water pump and continue recording the required parameters for the remainder of the test.

7.3.2. Recording Data

7.3.2.1. For units with pump purge functionality, record the initial heat exchanger outlet water temperature (T_{OHX}), and ambient room temperature when the main burner(s) cut-out or the fuel supply is turned off. After the pump purge operation is complete, record the time as t = 0 and the initial electricity meter reading. Continue to monitor and record the heat exchanger outlet water temperature (T_{OHX}) and time elapsed from the start of the test, and the electricity consumption as per the requirements in section 3.9.2 of this appendix.

7.3.2.2. For units not equipped with pump purge functionality, begin recording the measurements as per the requirements of section 3.9.2 of this appendix when the main burner(s) cut-out or the fuel supply is turned off. Specifically, record the time as t = 0, and record the initial heat exchanger outlet water temperature (T_{OHX}), ambient room temperature, and electricity meter readings. Continue to monitor and record the heat exchanger outlet water temperature (T_{OHX}) and the time elapsed from the start of the test as per the requirements in section 3.9.2 of this appendix.

7.3.3. *Stopping Criteria.* Stop the test when one of the following occurs:

7.3.3.1. The heat exchanger outlet water temperature (T_{OHX}) decreases by 35 °F from its value recorded immediately after the main burner(s) has cut-out, and the pump purge operation (if applicable) is complete; or

7.3.3.2. 24 hours have elapsed from the start of the test.

7.3.4. At the end of the test, record the final heat exchanger outlet water temperature (T_{OHX}), fuel consumed, electricity consumed from time t=0, and the time elapsed from the start of the test.

7.3.5. Standby Loss Calculation

7.3.5.1. Once the test is complete, use the following equation to calculate the standby loss as a percentage (per hour) of the heat content of the stored water above room temperature:

$$S = \frac{\frac{k(V_a)(\Delta T_1)}{E_t/100} + E_c}{k(V_a)(\Delta T_2)(t)} \times 100$$

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Where,

ΔT_1 = Heat exchanger outlet water temperature (T_{OHX}) measured after the pump purge operation is complete (if the unit is integrated with pump purge functionality); or after the main burner(s) cut-out (if the unit is not equipped with pump purge functionality) minus heat exchanger outlet water temperature (T_{OHX}) measured at the end of the test, expressed in °F

ΔT_2 = Heat exchanger outlet water temperature (T_{OHX}) minus the ambient temperature, both measured after the main burner(s) cut-out, at the start of the test, expressed in °F

K = 8.25 Btu/gallon· °F, the nominal specific heat of water

V_a = Volume of water contained in the water heater in gallons measured in accordance with section 4 of this appendix

E_t = Thermal efficiency of the water heater determined in accordance with section 6 of this appendix, expressed in %

E_c = Electrical energy consumed by the water heater during the duration of the test in Btu

t = Total duration of the test in hours

S = Standby loss, the average hourly energy required to maintain the stored water temperature expressed as a percentage of the initial heat content of the stored water above room temperature

7.3.5.2. The standby loss expressed in terms of Btu per hour must be calculated as follows:

SL (Btu per hour) = S (% per hour) × 8.25 (Btu/gal- °F) × Measured Volume (gal) × 70 (°F)

Where, SL refers to the standby loss of the water heater, defined as the amount of energy required to maintain the stored water temperature expressed in Btu per hour.

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Back to Top