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DEPARTMENT OF ENERGY

10 CFR Parts 429 and 430

[EERE-2022-BT-TP-0028]

Energy Conservation Program: Test Procedures for Central Air Conditioners and Heat Pumps

AGENCY: Office of Energy Efficiency and Renewable Energy, Department of Energy.

ACTION: Request for information.

SUMMARY: The U.S. Department of Energy ("DOE") is undertaking the preliminary stages of a rulemaking to consider amendments to the test procedure for central air conditioners and heat pumps. Through this request for information ("RFI"), DOE seeks data and information regarding issues pertinent to whether amended test procedures would more accurately or fully comply with the requirement that the test procedure produces results that measure energy use during a representative average use cycle or period of use for the product without being unduly burdensome to conduct, or reduce testing burden. DOE welcomes written comments from the public on any subject within the scope of this document (including topics not raised in this RFI), as well as the submission of data and other relevant information.

DATES: Written comments and information are requested and will be accepted on or before **[INSERT DATE 30 DAYS AFTER DATE OF PUBLICATION IN THE *FEDERAL REGISTER*]**.

ADDRESSES: Interested persons are encouraged to submit comments using the Federal eRulemaking Portal at *www.regulations.gov,* under docket number EERE-2022-BT-TP-0028. Follow the instructions for submitting comments. Alternatively, interested persons may submit comments, identified by docket number EERE-2022-BT-TP-0028, by any of the following methods:

Email: *CACandHeatPump2022TP0028@ee.doe.gov*. Include the docket number EERE-2022-BT-TP-0028 in the subject line of the message.

Postal Mail: Appliance and Equipment Standards Program, U.S. Department of Energy, Building Technologies Office, Mailstop EE-5B, 1000 Independence Avenue, SW., Washington, DC, 20585-0121. Telephone: (202) 287-1445. If possible, please submit all items on a compact disc ("CD"), in which case it is not necessary to include printed copies.

Hand Delivery/Courier: Appliance and Equipment Standards Program, U.S. Department of Energy, Building Technologies Office, 950 L'Enfant Plaza, SW., 6th Floor, Washington, DC, 20024. Telephone: (202) 287-1445. If possible, please submit all items on a CD, in which case it is not necessary to include printed copies.

No telefacsimiles ("faxes") will be accepted. For detailed instructions on submitting comments and additional information on this process, *see* section III of this document.

Docket: The docket for this activity, which includes *Federal Register* notices, comments, and other supporting documents/materials, is available for review at *www.regulations.gov*. All documents in the docket are listed in the *www.regulations.gov* index. However, not all documents listed in the index may be publicly available, such as information that is exempt from public disclosure.

The docket web page can be found at *www.regulations.gov/#!docketDetail;D=EERE-2022-BT-TP-0028*. The docket webpage contains instructions on how to access all documents, including public comments, in the docket. *See* section III for information on how to submit comments through *www.regulations.gov*.

FOR FURTHER INFORMATION CONTACT:

Mr. Lucas Adin, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Office, EE-2J, 1000 Independence Avenue, SW., Washington, DC, 20585-0121. Telephone: (202) 287-5904. E-mail: *ApplianceStandardsQuestions@ee.doe.gov*.

Mr. Pete Cochran, U.S. Department of Energy, Office of the General Counsel, GC-33, 1000 Independence Avenue, SW., Washington, DC, 20585-0121. Telephone: (202) 586-9496. E-mail: *peter.cochran@hq.doe.gov*.

For further information on how to submit a comment or review other public comments and the docket, contact the Appliance and Equipment Standards Program staff at (202) 287-1445 or by e-mail: *ApplianceStandardsQuestions@ee.doe.gov*.

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I. Introduction

Central air conditioners ("CACs") and central air conditioning heat pumps ("HPs") (collectively, "CAC/HPs") are included in the list of "covered products" for which DOE is authorized to establish and amend energy conservation standards and test procedures. (42 U.S.C. 6292(a)(3)) DOE's energy conservation standards and test procedures for CAC/HPs are prescribed at title 10 of the Code of Federal Regulations ("CFR"), part 430 section 430.32(c), and 10 CFR part 430, subpart B, appendix M1 ("appendix M1") (titled "Uniform Test Method for Measuring the Energy Consumption of Central Air Conditioners and Heat Pumps"). The following sections discuss DOE's authority to establish and amend test procedures for CAC/HPs as well as relevant background information regarding DOE's consideration of test procedures for this product.

A. Authority and Background

The Energy Policy and Conservation Act, as amended ("EPCA"),[1] authorizes DOE to regulate the energy efficiency of a number of consumer products and certain industrial equipment. (42 U.S.C. 6291–6317) Title III, Part B[2] of EPCA established the Energy Conservation Program for Consumer Products Other Than Automobiles, which

[1] All references to EPCA in this document refer to the statute as amended through the Energy Act of 2020, Pub. L. 116-260 (Dec. 27, 2020), which reflect the last statutory amendments that impact Parts A and A-1 of EPCA.
[2] For editorial reasons, upon codification in the U.S. Code, Part B was redesignated Part A.

sets forth a variety of provisions designed to improve energy efficiency. These products include CAC/HPs[3], the subject of this RFI. (42 U.S.C. 6292(a)(3))

The energy conservation program under EPCA consists essentially of four parts: (1) testing, (2) labeling, (3) Federal energy conservation standards, and (4) certification and enforcement procedures. Relevant provisions of EPCA specifically include definitions (42 U.S.C. 6291), test procedures (42 U.S.C. 6293), labeling provisions (42 U.S.C. 6294), energy conservation standards (42 U.S.C. 6295), and the authority to require information and reports from manufacturers (42 U.S.C. 6296).

Federal energy efficiency requirements for covered products established under EPCA generally supersede State laws and regulations concerning energy conservation testing, labeling, and standards. (42 U.S.C. 6297) DOE may, however, grant waivers of Federal preemption for particular State laws or regulations, in accordance with the procedures and other provisions of EPCA. (42 U.S.C. 6297(d))

The Federal testing requirements consist of test procedures that manufacturers of covered products must use as the basis for: (1) certifying to DOE that their products comply with the applicable energy conservation standards adopted pursuant to EPCA (42 U.S.C. 6295(s)), and (2) making other representations about the efficiency of those consumer products (42 U.S.C. 6293(c)). Similarly, DOE must use these test procedures to determine whether the products comply with relevant standards promulgated under EPCA. (42 U.S.C. 6295(s))

Under 42 U.S.C. 6293, EPCA sets forth the criteria and procedures DOE must follow when prescribing or amending test procedures for covered products. EPCA requires that any test procedures prescribed or amended under this section be reasonably designed to produce test results which measure energy efficiency, energy use or

[3] This rulemaking uses the term "CAC/HP" to refer specifically to central air conditioners (which include heat pumps) as defined by EPCA. (42 U.S.C. 6291(21))

estimated annual operating cost of a covered product during a representative average use cycle or period of use and not be unduly burdensome to conduct. (42 U.S.C. 6293(b)(3))

EPCA also requires that, at least once every 7 years, DOE review test procedures for all type of covered products, including CAC/HPs, to determine whether amended test procedures would more accurately or fully comply with the requirements that the test procedures are (1) reasonably designed to produce test results which reflect energy efficiency, energy use, and estimated operating costs during a representative average use cycle or period of use and (2) not unduly burdensome to conduct. (42 U.S.C. 6293(b)(1)(A)) If the Secretary determines, on her own behalf or in response to a petition by any interested person, that a test procedure should be prescribed or amended, the Secretary shall promptly publish in the *Federal Register* proposed test procedures and afford interested persons an opportunity to present oral and written data, views, and arguments with respect to such procedures. The comment period on a proposed rule to amend a test procedure shall be at least 60 days and may not exceed 270 days. In prescribing or amending a test procedure, the Secretary shall take into account such information as the Secretary determines relevant to such procedure, including technological developments relating to energy use or energy efficiency of the type (or class) of covered products involved. (42 U.S.C. 6293(b)(2)) If DOE determines that test procedure revisions are not appropriate, DOE must publish its determination not to amend the test procedures.

DOE is publishing this RFI to collect data and information to inform its decision in satisfaction of the 7-year review requirement specified in EPCA. (42 U.S.C. 6293(b)(1)(A))

B. Rulemaking History

DOE's energy conservation standards for CAC/HPs are currently prescribed at 10 CFR 430.32(c), and test procedure at 10 CFR part 430, subpart B, appendix M1.

On January 5, 2017, DOE published a final rule regarding the Federal test procedures for CAC/HPs. 82 FR 1426 ("January 2017 CAC TP final rule"). The January 2017 CAC TP final rule amended the current test procedure at that time, 10 CFR part 430, subpart B, appendix M ("appendix M") and established appendix M1, use of which was required beginning January 1, 2023, for any representations, including compliance certifications, made with respect to the energy use or efficiency of CAC/HPs. Appendix M provides for the measurement of the cooling and heating performance of CAC/HPs using the seasonal energy efficiency ratio ("SEER") metric and heating seasonal performance factor ("HSPF") metric, respectively. Appendix M1 specifies a revised SEER metric (*i.e.*, "SEER2") and a revised HSPF metric (*i.e.*, "HSPF2").

On October 25, 2022, DOE published a final rule to address limited-scope amendments to the existing test procedures for CAC/HPs in appendix M and appendix M1. 87 FR 64550 ("October 2022 CAC TP final rule"). The October 2022 CAC TP final rule provided changes to improve the functionality of appendix M1 to address the issues identified in test procedure waivers, improve representativeness, and correct typographical issues raised by commenters. *Id.* In the October 2022 CAC TP final rule, DOE noted that several commenters indicated the need for further test procedure amendments beyond the scope of the rulemaking. *Id.* at 87 FR 64554-64555. DOE received comments recommending consideration of load-based testing methods, controls validation (particularly for variable-speed systems), amended metrics, amended definitions, and expansion of test methods to capture low-temperature heating performance for heat pumps. *Id.* In its response to these comments, DOE noted that it had initiated the rulemaking not as a comprehensive revision that will satisfy the 7-year lookback requirements (*see* 42 U.S.C. 6293(b)(1)(A)), but to address a limited set of known issues, including those that have been raised through the test procedure waiver process. 87 FR 64554. However, DOE also responded that a future rulemaking may more comprehensively address the issues raised by the commenters. *Id.*

DOE has considered the issues raised by stakeholders in two separate categories: (1) consideration of load-based testing methodologies that have been in development by multiple organizations and whether certain aspects of these methodologies might be adopted into the DOE test procedure (this is discussed in section II.B of this RFI) and (2) issues with the current appendix M1 test procedure that may or may not still be relevant when/if load-based concepts are adopted in the DOE test procedure (these are discussed in sections II.C and II.D of this RFI).

In summary, DOE is publishing this RFI to collect data and information regarding the need for amendments to the test procedures for CAC/HPs, including the issues raised by the commenters in the previous rulemaking, and in satisfaction of the 7-year review requirement specified in EPCA.

II. Request for Information

In the following sections, DOE has identified a variety of issues on which it seeks input to determine whether, and if so how, an amended test procedure for CAC/HPs would (1) more accurately or fully comply with the requirements in EPCA that test procedures be reasonably designed to produce test results which reflect energy use during a representative average use cycle or period of use, without being unduly burdensome to conduct (42 U.S.C. 6293(b)(3)); or (2) reduce testing burden.

Additionally, DOE welcomes comments on any aspect of the existing test procedures for CAC/HPs that may not specifically be identified in this document.

A. Scope and Definitions

CAC/HPs are defined in 10 CFR 430.2. As laid out in section 1.1 of appendix M1, the test procedure applies to CAC/HPs including the following categories, all of which are defined either in 10 CFR 430.2 or in section 1.2 of appendix M1:

(a) Split-system air conditioners, including single-split, multi-head mini-split, multi-split (including variable refrigerant flow ("VRF")), and multi-circuit systems;

(b) Split-system heat pumps, including single-split, multi-head mini-split, multi-split (including VRF), and multi-circuit systems;

(c) Single-package air conditioners;

(d) Single-package heat pumps;

(e) Small-duct, high-velocity systems (including VRF);

(f) Space-constrained products—air conditioners; and

(g) Space-constrained products—heat pumps.

The definition for central air conditioner or central air conditioning heat pump was last amended in the October 2022 CAC TP final rule. DOE revised the central air conditioner or central air conditioning heat pump definition so that it explicitly excluded certain equipment categories that met the CAC/HP definition based on their characteristics but are exclusively distributed in commerce for commercial and industrial applications. 87 FR 64550, 64573. DOE noted that there are certain types of equipment that meet the CAC/HP definition but are exclusively distributed in commerce for commercial and industrial applications, and that EPCA did not intend to regulate as consumer products. *Id.*

Issue 1: DOE seeks information on whether the scope of CAC/HPs covered by appendices M and M1 needs to be limited, expanded, clarified, or revised in any way.

Issue 2: DOE seeks information on whether the definition of central air conditioner or central air conditioning heat pump needs revision or further clarifications.

B. Load-Based Testing

1. Background

As noted in section I.B of this RFI, several stakeholders in the previous rulemaking encouraged DOE to review ways to improve the representativeness of the test procedures for CAC/HPs. Specifically, the Pacific Gas and Electric Company, San Diego Gas and Electric, and Southern California Edison (collectively, the "California Investor Owned Utilities" or "CA IOUs"); the Appliance Standards Awareness Project ("ASAP") and American Council for an Energy-Efficient Economy ("ACEEE") (collectively, the "Joint Advocates"); and the Northwest Energy Efficiency Alliance ("NEEA") all requested that DOE explore approaches that would capture the performance of variable-speed and multi-stage systems operating under native controls rather than under fixed compressor and fan speed controls as required under the current DOE test methods. (CA IOUs, No. 20 at pp. 2–3; Joint Advocates, No. 18 at p. 1; NEEA, No. 23 at p. 1)[4]

NEEA and the Joint Advocates recommended that DOE adopt a test procedure that evaluates performance for variable-speed systems with the heat pump operating using its native controls rather than using fixed-speed overrides of controls. (NEEA, No.

[4] The parenthetical reference provides a reference for information located in the docket of DOE's rulemaking to develop test procedures for central air conditioners and heat pumps (Docket No. EERE–2021–BT–TP-0030, which is maintained at *www.regulations.gov*). The references are arranged as follows: (commenter name, comment docket ID number, page of that document).

23 at p. 1; Joint Advocates, No. 18 at pp. 3–4) NEEA provided data to support their claim that seasonal efficiency performance is highly dependent on the installed firmware of the system. (*Id.* at pp. 3–4) NEEA compiled this information in a report[5] that was also cited by the Joint Advocates in their comment. (Joint Advocates, No. 18 at p. 4)

NEEA also requested that DOE adopt a load-based test procedure with the tested system operating under native controls. (NEEA, No. 23 at p. 2) NEEA again provided data concerning the representativeness of the existing DOE test procedure as compared to field data. *Id.* NEEA cited several ongoing projects related to the evaluation of load-based testing of CAC/HP and recommended that DOE leverage this work as a part of the next CAC/HP test procedure rulemaking. (*Id.* at pp. 5–7) NEEA additionally requested that DOE consider increasing the amount of data reported for heat pumps operating at part-load heating conditions, specifically advocating for required reporting of coefficient of performance ("COP") for low-compressor-stage tests at 67°F and 47°F. (*Id.* at p. 7)

To address these comments, and in addition to the potential improvements in appendix M1 outlined in sections II.C and II.D of this RFI, DOE is exploring the potential of a load-based testing approach, primarily for variable-speed CAC/HPs, to evaluate performance characteristics that may not be captured by the existing steady-state test methods outlined in appendix M1. DOE has also considered load-based test methods that are also applicable for single- and two-stage models. This section gives a brief

[5] The report titled "Heat Pump and Air Conditioner Efficiency Ratings: Why Metrics Matter" outlined how the built-in firmware of variable-speed CAC/HPs can have a significant impact on real-world performance, yet the firmware operation is explicitly excluded from current rating procedures. The report presented the case that a much better rating metric would utilize a load-based testing procedure that fully characterizes heat pump performance under realistic operating conditions, including the systems' built-in firmware. Available at *https://neea.org/resources/heat-pump-and-air-conditioner-efficiency-ratings-why-metrics-matter*.

introduction of the load-based testing methodologies and summarizes the various efforts and test programs that are investigating and developing new load-based test methods.

2. Current DOE Test Procedures

As discussed, the current test procedures for CAC/HPs are given at title 10 CFR part 430, subpart B, appendix M1. Beginning January 1, 2023, manufacturers must certify their systems under appendix M1 and meet energy conservation standards in terms of EER2, SEER2, HSPF2, and off-mode power.

a. Test Conditions

Appendix M1 uses a steady-state test concept where test room conditions are kept within narrow operating tolerances for each test point, and the CAC/HP system is manually controlled to operate at the specified compressor speed and airflow rate for each test point (*i.e.*, the CAC/HP system's controls are overridden to ensure constant operation at the speed and airflow required by the DOE test procedure). While the DOE test procedures do include transient tests to examine the impact of defrost and compressor cycling, they do not incorporate any elements of load-based testing[6] in which the unit operates under its own native controls in responding to conditioning loads. Several research projects discussed in section II.B.4 have addressed development of load-based test approaches.

[6] A load-based test method differs from the steady-state test method currently used in DOE test procedures for air conditioning and heat pump equipment. In a steady-state test method, the indoor room is maintained at a constant temperature throughout the test. In this type of test, any variable-speed or variable-position components of air conditioners and heat pumps are set in a fixed position, which is typically specified by the manufacturer. In contrast, a load-based test has the conditioning load applied to the indoor room using a load profile that approximates how the load varies for units installed in the field. In this type of test, an air conditioning system or heat pump is allowed to automatically determine and vary its control settings in response to the imposed conditioning loads, rather than relying on manufacturer-specified settings.

Furthermore, there has been growing interest in cold climate heat pumps ("CCHPs"). A CCHP is a kind of central heat pump that could provide mechanical air heating utilizing a refrigerant vapor compression cycle, or a combination of mechanical air heating and electric resistance heating, at low outdoor ambient conditions (~5°F) that could occur in generalized climate region V[7] in the United States. On May 19, 2021, DOE, in conjunction with the U.S. Environmental Protection Agency ("EPA") and National Resources Canada ("NRCan"), announced a Cold Climate Heat Pump Technology Challenge ("DOE CCHP Tech Challenge") as part of the Energy, Emissions and Equity ("E3") Initiative[8]. In partnership with heat pump manufacturers, DOE developed a new technology specification for a high-performance CCHP. Several CCHP prototypes meeting this technology specification will undergo field trials in the winters of 2022 and 2023 to demonstrate performance in the field. In addition to the interest in CCHP development expressed by heat pump manufacturers, DOE is aware of growing interest from utilities and state governments to support the development of CCHPs to accelerate decarbonization efforts (*e.g.*, replacing residential furnaces with heat pumps). Utility programs often offer rebates to consumers who purchase high-efficiency products, and high-performing CCHP are a growing component of several utility rebate programs.[9]

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[7] *See* "Figure 1 – Climatic Regions I through VI for the United States" in appendix M1.
[8] As part of the E3 Initiative, DOE launched the DOE CCHP Tech Challenge. Currently, the challenge is focused on residential, centrally ducted, electric-only HPs. CCHP products that meet the challenge specification would offer high efficiency and heating capacity both seasonally and at very cold temperatures (5°F and below). The challenge builds upon the recent ENERGY STAR specification (v6.1). For further details, *see www.energy.gov/sites/default/files/2022-02/bto-cchp-fact-sheet-021822.pdf*
[9] There currently is a database of CCHP products provided by the Northeast Energy Efficiency Partners ("NEEP"), and some utility providers are offering rebates if customers purchase and install a CCHP from the NEEP database. For example, the Vermont Public Power Supply Authority is offering one (*vppsa.com/2021-cold-climate-heat-pump-instant-discount/*).

However, the validation of CCHP performance at colder outdoor ambient temperatures (*i.e.*, 5° F and colder), is not a topic currently addressed by the DOE test procedures.

b. Control inputs

When testing for single-speed and two-speed CAC/HPs, the heating and cooling tests per the DOE test procedures are conducted using each of the discrete compressor speeds at which the system is capable of operating. However, when testing variable-speed CAC/HPs, appendix M1 requires selection of appropriate compressor speeds that are intended to be representative of how the system would operate under its native controls.[10] The DOE test procedures include some specification as to how compressor speeds should be selected for testing variable-speed CAC/HP. For example, appendix M1 specifies that for the $H3_2$ heating test, the "Heating Full" compressor speed should be the maximum speed at which the system controls would operate the compressor in normal operation at 17°F ambient temperature. However, there is no process for verifying that the compressor speeds selected for testing agree with the compressor speed that would be observed if the system were operating at the same conditions under native controls.

Additionally, single-speed and two-speed CAC/HP systems rely on voltage signals from a thermostat to determine their operating state. When following DOE's test procedures for single-speed and two-speed CAC/HPs, it is common practice for the test lab to simulate a thermostat signal by sending the appropriate voltage signals directly to the unit under test instead of using a functional thermostat to induce the desired stage of

[10] Native controls means configuring the unit under test with settings specified for field use and removing the unit from "test mode" used for steady-state tests. Native control settings are determined from manufacturer installation and operations manual shipped with the unit.

heating or cooling mode. Conversely, variable-speed CAC/HPs installed in the field commonly utilize communicating thermostats where the control system communicates the difference in space temperature and space setpoint temperature to the control that sets compressor speed and indoor fan speed. Manufacturers involved in the development of the ENERGY STAR Central Air Conditioner and Air Source Heat Pump Specification Version 6.0 indicated that standard thermostats for their variable-speed units enable two-way communication control between the indoor and outdoor units.[11] DOE is aware of concerns that two-way communication control may not be possible using a third-party smart thermostat or lab-simulated thermostat. Therefore, many variable-speed units would not operate without their proprietary communicating thermostat making it an inherent part of the native control. DOE is also aware of concerns that operation under native controls for variable-speed CAC/HP can result in dynamic operation that is inconsistent with the steady-state requirements in the current DOE test procedure.

3. Categorization of Test Concepts

As explained in section II.B.1 of this document, the current DOE test procedure for CAC/HPs outlined in appendix M1 is a steady-state test, where the compressor speeds and airflow rates may be overridden for each test point.

In contrast, a load-based test has the conditioning load applied to the indoor room using either a stable compensation load or a load profile that approximates how the load varies for units installed in the field. In this type of test, an air conditioning system or

[11] Lennox and Carrier comments on the Version 6.0 Limited Topic Proposal on Installation, dated February 23, 2021. Comments are accessible at *https://www.energystar.gov/products/spec/central_air_conditioner_and_air_source_heat_pump_specification_version_6_0_pd*.

heat pump is allowed to automatically determine and vary its operation in response to the imposed conditioning loads, rather than operating at manually overridden speeds.

Because of the different variations of load-based tests, it is important to define the method of inducing the conditioning load on the indoor psychrometric room. Broadly, there are two methods of inducing load, which are detailed in the following sections II.B.3.a and II.B.3.b of this document.

a. Test Chamber Induced Load

In this approach, the test chamber's reconditioning equipment, and/or any alternative devices such as a fan coil or electric heater, add or remove heat to (or from) the chamber at a constant rate. An example of the test chamber induced load is the load-compensation method, which was first proposed by the German energy regulatory body, Bundesanstalt für Materialforschung und-Prüfung ("BAM").[12] Like all load-based tests, the load-compensation method involves testing the CAC/HP equipment operating without any test unit native controls override (*i.e.*, not in test mode). This approach minimizes the impact on test result variation caused by test chamber and measurement apparatus thermal mass due to the inherent steady-state nature of the testing.

This testing methodology can be illustrated by explanation of its execution in the DOE CCHP Tech Challenge. Prior to conducting load-compensation tests under native controls, appendix M1 tests are required to calculate HSPF2 and determine target compensation loads for a select sub-set of native control tests. During native control testing, the psychrometric chambers are operated with a fixed cooling load; this load

[12] BAM (2019). *Proposal for the revision of the harmonised test standard EN 14825:2016*. Federal Institute for Materials Research and Testing (BAM).

should be equivalent in magnitude to the capacity from the corresponding appendix M1 regulatory test. Full-load tests are conducted with the thermostat set at the maximum available setpoint unless temporary over speeding is allowed by the system controls. In this case, the thermostat setpoint is reduced until temporary over speeding is no longer occurring. Minimum and intermediate speed tests are conducted with the thermostat set at the test condition target value (adjusted for thermostat offset). For example, if a heating capacity of 17,000 Btu/h was measured during the $H1_1$ test, the "Min/Mild" test would apply an equivalent 17,000 Btu/h cooling load to the indoor room's conditioning equipment. This results in the unit under test responding to the test chamber-induced load to maintain the desired temperature. If a similar capacity cannot be achieved without the unit cycling on and off, then the compensation load is incrementally increased until the unit is no longer cycling. Data is collected with the unit operating at a capacity as close as possible to the ratings test while running continuously (not cycling).

b. Virtual Building Load

The Virtual Building Load ("VBL") approach of load-based testing adds to the load-compensation approach by simulating the building response to the conditioning provided by the unit under test. Specifically, if the system capacity is lower than the average load in a heating test, the temperature of the air returned to the unit would be reduced (by the test chamber conditioning equipment) to reflect the transient reduction in temperature of the building while the load and unit capacity are not balanced. The main difference between the test chamber induced load test method and the VBL test method is that the former utilizes a stable load being imposed on the unit under test, whereas the latter varies the load to simulate the building response if the capacity of the unit under test does not match the imposed load. Several variations exist for implementation of the VBL for load-based testing of CAC/HPs, as detailed in section II.B.4 of this RFI. What all these variations have in common is that the indoor room temperature varies to mimic the response of the virtual building, which is a software loop continuously interacting with the indoor room's conditioning equipment.

4. Summaries of Selected Activities Investigating and Developing New Test Methods for Central Air Conditioners and Heat Pumps

Several initiatives to investigate, research, and develop new test procedures have emerged in response to concerns that current regulatory test methods may have issues representing field performance. Some of these activities are described in the subsections below.

a. CSA EXP07

In March 2019, The Canadian Standards Association ("CSA") published a draft "first edition" of CSA EXP07:19, "Load-based and climate-specific testing and rating procedures for heat pumps and air conditioners"[13] ("EXP07"). EXP07 is a load-based testing methodology applicable to single-split and packaged air-source CAC/HP with rated cooling or heating capacity below 65,000 Btu/h, including space-constrained and small-duct, high-velocity equipment. In contrast to conventional test methods, in which the indoor room conditions are held constant by the laboratory's indoor room conditioning equipment, EXP07 allows the unit under test to respond to a thermostat or temperature controller installed in the room or the return air, while the indoor room conditioning equipment is controlled to adjust that temperature to represent the

[13] CSA EXP07:19 is available for purchase in the CSA Group online store at *www.csagroup.org/store/product/CSA%20EXP07%3A19.* A total of 86 different comments were received by stakeholders regarding EXP07:19 during a technical review. A summary of the major comments is detailed in this article: Bruce Harley, Mark Alatorre, Christopher Dymond, Gary Hamer, "CSA EXP07: Ongoing Progress, Lessons Learned, and Future Work in Load-based Testing of Residential Heat Pumps" (2022). International Refrigeration and Air Conditioning Conference. Paper 2477.

conditioning (be it heating or cooling) provided by the unit as well as the response of a typical building. The test sequences through a set of representative outdoor room conditions. As the unit attempts to maintain a desired condition, all modulating components are free to perform under the unit's own native controls.

The load-based test concept that underpins the EXP07 procedure is heavily dependent on the interaction of the unit under test, the test chambers, and the thermostat. For CAC/HP systems equipped with a communicating control system, typical for variable-speed systems, the thermostat calculates the difference between the measured indoor room temperature and the unit setpoint for the indoor room, and continuously sends signals to the unit under test to control its operating state. CSA EXP07 also requires that the make and model of the thermostat be recorded and reported with test data.

b. AHRI 1230-2021 VRF CVP

On May 18, 2021, the Air-Conditioning, Heating, and Refrigeration Institute ("AHRI") published an updated test procedure (AHRI 1230-2021) for Variable Refrigerant Flow Multi-Split Air Conditioners and Heat Pumps that incorporates a controls verification procedure ("CVP") as appendix C[14] ("VRF CVP"). AHRI 1230-2021 allows manufacturers to specify control settings for certain "critical parameters" (*e.g.*, compressor speed, outdoor unit fan speed, and outdoor unit valve positions) in supplemental testing instructions; the VRF CVP is then used to verify whether these manufacturer-specified critical parameter settings are within the range of settings that would be used by the system during operation in the field. On October 20, 2022, DOE

[14] *See www.ahrinet.org/sites/default/files/2022-06/AHRI_Standard_1230-2021.pdf.*

published a Final Rule regarding Federal test procedures for VRFs. 87 FR 63860 ("October 2022 VRF TP final rule"). In the October 2022 VRF TP final rule, DOE incorporated the CVP (via reference to Appendix C of AHRI 1230-2021) as part of DOE's product-specific enforcement provisions for VRF multi-split systems in the proposed §429.134(s). *Id.*

The VRF CVP is performed in the cooling mode by using the test room conditioning apparatus to continuously reduce the indoor room temperature throughout the duration of the procedure. The VRF system responds as the temperature decreases and "unloads" as the demand diminishes for the system to provide cooling capacity. Throughout the CVP, the measured positions of each critical parameter are compared against the certified critical parameter values. The certified critical parameters are validated if a defined time exists from within the CVP where the measured values are within tolerance of the certified values. The VRF CVP is not used to measure capacity or efficiency; it is solely used for validating whether critical parameter control inputs are representative of behavior as observed under native control. Additionally, the VRF CVP is not a fully load-based method.

The VRF CVP includes test provisions that are specific to the operation of VRF systems, such as requirements governing the number of thermally active indoor units and validation of critical parameters that are all variable-speed or modulating-position. Additional specification would be required to adapt the AHRI 1230-2021 CVP for VRF systems into a similar CVP applicable for CAC/CHP equipment intended to validate the operating states of variable-speed or modulating components. It is important to note that the VRF CVP utilizes a dynamic load that is neither constant nor simulates a virtual building load. The magnitude of the load is dynamically decreased by explicitly requiring the indoor temperature to be ramped down.

c. ENERGY STAR CCHP CVP

On January 27, 2022, EPA published the ENERGY STAR Version 6.1 Specification for CACs and Air-Source Heat Pumps ("ASHPs").[15] To certify as an ENERGY STAR CCHP, systems must also meet criteria at the 5°F heating test condition and perform a controls verification procedure to confirm that the system achieves the same capacity and efficiency criteria at the 5°F test point when operating under native controls. The ENERGY STAR CCHP CVP is used as pass/fail verification criteria, rather than being used to develop a discrete performance rating, and the system must meet verification criteria in terms of capacity and efficiency.

The ENERGY STAR CCHP CVP shares aspects of both load-based testing and controls verification procedures. The method is similar to other load-based test procedures in that the test unit operates under its native controls. During the ENERGY STAR CCHP CVP, the system thermostat is set to the highest achievable setpoint, while the indoor room conditioning apparatus is set to control to the standardized 70 ºF indoor room temperature used for heating tests.[16] In cases in which the required capacity is exceeded but the COP is lower than the requirement, a modified test is allowed, in which the operating capacity is reduced, to attempt to shift both capacity and COP into compliance with the requirement. For this modified test, the thermostat setting is reduced

[15] *See www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%206.1%20Central%20Air%20Conditioner%20and%20Heat%20Pump%20Final%20Specification%20%28Rev.%20January%20%202022%29.pdf.*

[16] This is referred to as a "buried thermostat" test. The "buried" term arose from use of the approach in cooling mode testing, for which the term is consistent with using the lowest setting.

to the standardized room temperature, and the load applied to the room is reduced. If the system can operate at a balance point where both the COP and heating capacity requirements are met, then the CCHP CVP is successful. This part of the ENERGY STAR CCHP CVP is a load-based method, since the chamber conditioning system applies a fixed load rather than maintaining chamber temperature.

d. BAM Dynamic Testing Method

On May 29, 2019, BAM proposed a load-based (compensation method) test method ("Proposal for the revision of the harmonized test standard EN 14825, for the testing and rating of air conditioners and heat pumps at part load conditions and calculation of seasonal performance"), to be used as an alternative to EN 14825:2016 "Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling. Testing and rating at part load conditions and calculation of seasonal performance" ("EN 14825"). The proposal outlined several issues[17] with the fixed compressor speed standard, EN 14825.

After consultations with stakeholders, BAM released test guidelines based on their load-based test method on September 21st, 2020, for ducted and non-ducted, single-split and packaged air-source CAC/HPs with rated cooling or heating capacity below 41,000 Btu/h in a single or double calorimeter room ("Test guideline for a load-based performance testing and calculation of the seasonal performance (air conditioners, cooling only)")[18].

[17] Section 2.3; May 29th BAM Proposal.
[18] *See*: *netzwerke.bam.de/Netzwerke/Content/DE/Downloads/Evpg/Heizen-Kuehlen-Lueften/bam%20test%20guideline%20-%20load-based%20testing%20of%20air%20conditioners%20cooling.pdf.pdf?__blob=publicationFile*

Through round-robin testing of CAC/HP units using the fixed compressor speed test procedure at seven different test labs, BAM found the standard deviation of reproducibility for EN 14825 to be 7.8% with a maximum deviation of 24% of Seasonal COP values.[19] [20] BAM did undergo some limited investigation of the repeatability and reproducibility of the BAM Dynamic Testing method, and BAM claims that their test method is both repeatable and reproducible.[21] They found the degree of repeatability using the BAM Dynamic Testing method to be comparable (~2%) to the repeatability of the current fixed compressor speed standard, EN 14825.[22]

BAM evaluated 15 CAC models during their preliminary testing for the BAM Dynamic Testing method and found that the unfixed compressor speed load compensation method results in, on average, an approximately 20% lower SEER compared to declared values.[23] The reason for this deviation was primarily due to varying behavior at part-load conditions, typically when the outdoor ambient temperature was between 77 °F and 86 °F. Due to the different control strategies in each of the CACs, the pattern of cycling on and off varied unit to unit, and hence affecting the SEER values. BAM observed that the compensation method allowed for a better comparison between units with well-designed control systems.

[19] Figure 4a, 29th May 2019 BAM Proposal. BAM cites that many any labs were erroneously assuming various correction factors due to ambiguities in EN 14825, and without the need for these correction factors in a dynamic test procedure, BAM predicts that reproducibility will be higher.

[20] Table 2, 29th May 2019 BAM Proposal; BAM has not released substantial test data on the reproducibility of their test procedure in comparison to the European standard. Instead, they hypothesize that without the ambiguities found in EN 14825 or correction factors, the BAM Dynamic Test procedure will be more reproducible.

[21] Figure 10 in the May 29, 2019, proposal features a distribution of some of these results, but the document does not provide substantiating data to back up their claim of repeatability and reproducibility.

[22] "Results" section, 29th May 2019 BAM Proposal.

[23] Figure 6, 29th May 2019 BAM Proposal. This figure displays results from testing to the unfixed compressor, load compensation method defined in section 8.5.2 of EN 14825. This method is not exactly what the BAM Dynamic Testing method is, but the BAM Dynamic Testing method is largely based off this.

e. 4E IEA

The Technology Collaboration Program on Energy Efficient End-use Equipment, International Energy Agency ("4E TCP") studied various load-based testing techniques in order to see if it is possible to develop a test method that improves testing representativeness of variable-speed central air conditioners.[24] 4E TCP conducted the testing series (titled "Project 2.0") where three different variable-speed CAC/CHP units were tested by utilizing aspects of published load-based test procedures (BAM Dynamic Testing, CSA EXP07 and AHRI 1230 CVP).

4E TCP presented their findings in a public webinar[25] and solicited feedback from stakeholders on the preferred test concept to be used in a unified load-based test method. After investigative testing, 4E IEA recommended either a compensation target load-based method (if test condition/test operating tolerances, repeatability and burden increases are acceptable to stakeholders), or a CVP would be preferred if the tolerances and burden are not acceptable. They also found that the dynamic load response test method is not repeatable in a laboratory setting. Stakeholders indicated the projected 10% - 15% repeatability increase for a compensation target load-based test was too large and that for regulatory purposes, the overridden steady-state test would be preferred.

On December 1, 2021, 4E IEA published a test method in "Controls Validation Method for Variable Speed Air Conditioners and Heat Pumps" ("4E TCP AC/HP Controls Validation Method"). This test method utilized the compensation target load-

[24] "Load-based Testing for Variable Speed Air Conditioners & Heat Pumps Phase 1 Findings Webinar" 4E IEA presentation (January 29, 2021). See *https://www.iea-4e.org/wp-content/uploads/2021/08/AC-HP-Test-Methods-Phase-1-Key-Findings_Revised.pdf* .

[25] "AC/HP Test Methods Investigative Testing: Phase 2 Preliminary Findings" 4E IEA presentation (May 7, 2021). See *https://www.iea-4e.org/wp-content/uploads/2021/08/AC-HP-Test-Methods-Phase-2-key-Findings-2021-08-06-CLEAN.pdf.*

based method as a CVP for confirmation against regulatory tests in which modulating component(s) are overridden. This methodology is applicable to variable-speed ducted and non-ducted single-split and packaged air-source CAC/CHP with rated cooling or heating capacity below 65,000 Btu/h, including through-the-wall air conditioners (“ACs”) and heat pumps (“HPs”).

f. DOE Cold-Climate Heat Pump Investigative Testing

To inform the development of test methods for Cold Climate Heat Pump Test methods, DOE conducted investigative testing on 7 non-ducted mini-split and 2 central-ducted split variable-speed heat pumps. All heating regulatory tests as per appendix M/M1 were conducted, in addition to the $H4_2$ test at 5°F (optional in appendix M1), $H5_2$ test at -5°F, and $H6_2$ test at -15°F (not part of appendix M or M1). Load-based tests were conducted using the load-compensation method for select appendix M1 conditions, denoted by the “x” subscript, namely $H1_{Nx}$, $H1_{1x}$, and $H4_{2x}$. The testing showed that regulatory and load-based tests showed similar performance for ducted units at 47°F heating maximum air volume rate condition ($H1_N$ and $H1_{Nx}$). However, DOE found that regulatory tests did not capture “real-world” performance at ambient temperatures lower than 47°F. Specifically, DOE observed that the compressor speeds and indoor fan speeds for load-based and regulatory tests at ambient temperatures below 47°F differed by more than 11% for some of the tested units. Additionally, DOE observed that units in “test mode” allowed operation below the point at which the native control tests cut out.

g. DOE CCHP Tech Challenge

Performance of the CCHPs participating in the DOE CCHP Tech Challenge (see II.B.2 for further details) is evaluated by testing at the psychrometric chambers at Oak

Ridge National Laboratory ("ORNL"). The test matrix comprises the regulatory heating mode tests outlined in appendix M1, with the $H4/H4_2$ test at outdoor ambient temperature of 5°F being mandatory. Additionally, after consultation with manufacturers, it was decided that a battery of CCHP-Focused Dynamic Tests would be conducted based on the load-compensation method[26]. For variable-speed CCHPs to pass the DOE CCHP Tech Challenge specifications, one of the requirements is that the minimum capacity at 47°F, validated using the "Min/Mild" load-based test, shall be at least 30% less than the nominal capacity at 47°F (*i.e.*, capacity for test $H1_N$ of appendix M1). So far, 10 manufacturers have committed to participate in the DOE CCHP Tech Challenge, with three of them having successfully achieved the challenge's standards to date[27].

h. Emulator-Based Assessment Method for Dynamic Performance Evaluation of Air Conditioners by Waseda University

Various groups at the Waseda University in Japan collaborated to develop an emulator-based method for load-based testing of ACs[28]. The virtual room emulator simulates the return indoor air temperature based on the input assumptions for a VBL. Consequently, the AC responds to the simulated indoor air conditions by supplying cooling capacity according to the response guided by its control system. Testing was conducted, with and without the emulator enabled, on a 2-ton non-ducted CHP, as per the conditions outlined in the Japanese Industrial Standards annual performance tests ("JIS B 08615, 2013") (*i.e.*, indoor dry-bulb and wet-bulb temperatures of 80°F and 67°F, respectively, and outdoor dry-bulb and wet-bulb temperatures of 95°F and 75°F,

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[26] *See www.energy.gov/sites/default/files/2021-10/bto-cchp-tech-challenge-spec-102521.pdf*
[27] *See www.energy.gov/articles/biden-harris-administration-announces-250-million-investment-inflation-reduction-act*
[28] Niccolo Giannetti, Hifni Ariyadi, Yoichi Miyaoka, Jongsoo Jeong, Kiyoshi Saito, "Development of an Emulator-Based Assessment Method for Representative Evaluation of the Dynamic Performance of Air Conditioners " (2022). International Refrigeration and Air Conditioning Conference. Paper 2458. *docs.lib.purdue.edu/iracc/2448/.*

respectively, at a 25 percent loading condition). It was found that the COP of the unit with the emulator enabled was 22 percent lower than the corresponding steady-state test (without the emulator).

As a result of testing, the team at Waseda University was able to identify several sources of errors and delays that affected the modulation of indoor air temperature and humidity, such as the emulator's calculation time delay, tracking of air flow rate, temperature and humidity by the condition generator, heat transfer and thermal capacity of the structure and instrumentation of the psychrometric chamber, time delay of the various signals, and the thermostat location.

i. The Advanced Heat Pump Coalition

The Advanced Heat Pump Coalition is a group of utilities and energy efficiency advocates, namely NEEA, the Northeast Energy Efficiency Partners ("NEEP"), the Midwest Energy Efficiency Alliance ("MEEA"), NRCan, EPA, California Energy Commission, and the New York State Energy Research and Development Authority ("NYSERDA"), that share knowledge and resources to assist the market adoption of residential heat pumps in the US[29]. Workgroup 1 of this coalition aims to identify a load-based test procedure for ASHPs that is more representative of their performance in the field.

Initially, 13 heat pumps made by nine manufacturers were tested using CSA EXP07:19 and AHRI 210/240[30] ("Performance Rating of Unitary Air-conditioning & Air-source Heat Pump Equipment") at the UL Plano laboratory in Texas. Two were

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[29] *See www.mwalliance.org/advanced-heat-pump-coalition*

[30] AHRI 210/240 establishes a method to rate residential central air conditioners and heat pumps consistent with the test procedure codified in 10 CFR part 430, subpart B, appendix M1.

initially tested only in the heating mode and 11 were tested in both heating and cooling modes to generate a complete set of seasonal COP ratings. As previously mentioned, EXP07 accounts for the on-board control algorithms of the units under test. A comparison of the relationship between HSPF and heating SCOP or SEER and cooling SCOP was not conducted due to the fact that these are two different metrics based on different measurement conditions and methodologies. However, comparing different models with similar SEER and HSPF ratings to the results using the CSA EXP07 method showed that the relative efficiencies of those models were significantly different. The Coalition stated that the on-board controls are a critical component of the heat pump's real performance and should be accounted for in future test standards.

j. ISO/TC 86/SC 6/TG 13

TG 13 ("Next generation of performance standards") is a working group of ISO/TC 86/SC 6 ("Testing and rating of air-conditioners and heat pumps") that is responsible for gathering information on various activities pertaining to load-based testing methods for residential CAC/HPs. Recently, lab testing results of several CAC/HPs using the BAM Dynamic Testing Method (section II.B.4.d of this document), CSA-EXP07:2019 (section II.B.4.a of this document), and the emulator-based assessment method (section II.B.4.h of this document), along with findings of the 4E IEA project (section II.B.4.e of this document), have been presented to members of ISO/TC 86/SC6/TG 13. The subcommittee has raised concerns about the repeatability and reproducibility of load-based tests on several occasions (*e.g.*, the "Load-based test method" informal virtual meeting held on July 8th, 2022), and hence encourage all ongoing and future research projects to address both of these factors.

k. ASHRAE TC 8.11 Subcommittee Unitary Next Generation Test Procedure

The American Society of Heating, Refrigerating and Air-Conditioning Engineers ("ASHRAE") Technical Committee ("TC") 8.11[31] is concerned with the following AC and HP systems: (1) ducted unitary ACs/HPs, (2) room ACs such as window mounted units and non-ducted split systems, and (3) packaged terminal equipment. The TC 8.11 subcommittee titled "Unitary Next Generation Test Procedure Subcommittee" was developed with the aim of coordinating technical activities related to the development of the next generation load-based test procedure for unitary HVAC equipment. It is planning to develop a Research Topic Acceptance Request ("RTAR"), which will enable identification of ASHRAE Research Projects ("RPs") to improve upon the reproducibility, repeatability, and representativeness of load-based test procedures for residential and commercial unitary AC/HP equipment.

5. Request for Information

As explained in section II.B.3, all load-based test methods are characterized by how the load is applied on the test chamber. Two primary testing procedures are used for capacity measuring, namely the calorimetric or air enthalpy method. The calorimetric room method measures the energy input to the equipment serving a known load added into the conditioned room. Test chambers are typically limited to a 3.4-ton (12 kW) cooling capacity and are typically preferable for testing non-ducted CAC/HPs. In contrast, the air enthalpy method is typically employed in psychrometric chambers, and is geared towards ducted equipment, but can accommodate non-ducted if needed. Table II-1 shows which of the two capacity measuring methods (*i.e.*, calorimetric room or air

[31] ASHRAE's technical committees are responsible for coordination of society-sponsored Research Projects ("RPs"), reviewing technical papers, evaluating the need for standards, and acting as the advisory board for the Society on all aspects of the technology for which it is in charge.

enthalpy) are used for each load-based test method, and also show the load application scheme for each of them.

Table II-1: Applicability of Load-Based Test Methods to Equipment Types, and Procedure for Capacity Measurement

Load-Based Test Method	Test Procedure for Capacity Measurement		Type of Equipment Test Method is Applicable To		Load Application Scheme	
	Calorimetric Room	Air Enthalpy Method	Ducted	Non-Ducted	Test Chamber Induced Load	Virtual Building Load
CSA EXP07	-	✓	✓	✓	-	✓
AHRI 1230-2021 VRF CVP	-	✓	✓	✓	✓	-
Energy Star CCHP CVP	-	✓	✓	✓	✓	-
BAM Dynamic Testing Method	✓	-	✓	✓	✓	-
DOE CCHP Investigative Testing	-	✓	✓	-	✓	-
DOE CCHP Tech Challenge	-	✓	✓	-	✓	-
Emulator-Based Assessment Method for Dynamic Performance Evaluation of ACs	✓	-	-	✓	-	✓
4E TCP AC/HP Controls Validation Method	✓	✓	✓	✓	✓	-

In the following sections, DOE has identified a variety of issues on which it seeks input to determine whether, and if so, how, an amended test procedure for CAC/HPs and CCHPs would more accurately or fully comply with the requirements in EPCA that test procedures be reasonably designed to produce test results that reflect energy use during a representative average use cycle or period of use without being unduly burdensome to conduct (42 U.S.C. 6293(b)(3)). DOE also seeks input on the most appropriate application of such an amended test procedure.

a. Repeatability and Reproducibility

DOE is interested in information and data regarding the repeatability and reproducibility of known load-based test methods. Publicly available information on this topic for the load-based test method initiatives discussed in section II.B.4 is very limited. Presentations regarding the 4E IEA work on development of load-based test procedures (*see* section II.B.4.e of this document) include claims that the degree of repeatability and reproducibility of load-based test procedures is extremely important, and through testing three different units twice at different test labs, the COP was found to vary as much as 10.6 percent during the load compensation method.[32] In addition, several units have been tested at two laboratories to assess the repeatability and reproducibility of CSA EXP07 and AHRI 210/240, but the information is only available to ISO/TC 86/SC 6/TG 13 and not to the public. DOE is aware of ongoing efforts where it has been pointed out during

[32] Slide 24 of "AC/HP Test Methods Investigative Testing: Phase 2 Preliminary Findings" 4E IEA presentation (May 7, 2021).

load-based testing that thermostat location within the indoor environmental chambers is very crucial for repeatability of load-based tests across different laboratories[33].

Issue 3: DOE requests quantitative information regarding the repeatability and reproducibility of load-based test procedures (not limited to the developments discussed in section II.B.4 of this RFI). Specifically, which of the approaches presented in section II.B.4 are better in this regard, and what specific characteristics make them better? How do the repeatability and reproducibility of load-based test procedures compare to more conventional test methods that involve operating the system with one or more fixed control setting? To what extent do the differences in test facility characteristics lead to different settings of control system parameters as a result of control system learning (i.e., adaptation of control parameters in response to "conditioned system" behavior) and how much does this affect different load-based test approaches? Please provide appropriate data to the extent possible to support the information.

b. Field Performance

As described in sections II.B.1 and II.B.2 of this RFI, stakeholders have expressed greater interest in load-based test procedures based on the observation that variable-speed CAC/HPs may not always operate in the field in a manner that is represented by conventional testing using fixed speeds for the compressor and other key components. Developers of load-based testing methods claim these tests are more representative of an average use cycle than the fixed compressor speed methods found in appendix M1.

[33] Cheng, Li; Patil, Akash; Dhillon, Parveen; Braun, James E.; and Horton, W. Travis, "Impact of Virtual Building Model and Thermostat Installation on Performance and Dynamics of Variable-Speed Equipment during Load-based Tests" (2018). International Refrigeration and Air Conditioning Conference. Paper 2078. *docs.lib.purdue.edu/iracc/2078.*

However, comprehensive information comparing the results of different test methods with the results of field operation have not been made public. Currently, DOE is only aware of NEEP managing a field performance research study to directly compare the representativeness of both EXP07 and appendix M1, but the results of this research are expected in the 2nd quarter of 2023[34].

Issue 4: DOE seeks data showing how the representativeness of load-based test procedures compares to that of more conventional fixed-speed and fixed-setting test procedures. What are the key issues observed that cause field performance of CAC/HPs to deviate from the predictions of conventional testing, and has load-based testing provided more representative predictions? Additionally, DOE is interested in any data suggesting that CAC/HPs that were considered to be performing poorly in the lab when tested using load-based methods also performed poorly when installed in the field.

c. Test Burden

In addition to considering repeatability, reproducibility, and representativeness when evaluating test procedures, DOE must also consider the relative burdens associated with conducting test procedures. One component of test burden is the total testing time, which includes setup/commissioning/decommissioning, official test points, and any time required to transition between test conditions. Test burden also accounts for difficulties in repeatably achieving test conditions (*i.e.*, whether a test has a higher likelihood of needing to be conducted multiple times to achieve a valid result). Another key component of analyzing test burden is considering any upgrades to laboratory equipment

[34] *See neep.org/request-proposals-heat-pump-rating-representativeness-project-0*

or capital expenditures required to conduct testing. These upgrades may constitute considerable burden when large capital expenditures are required.

Issue 5: DOE seeks information related to the test burden of load-based test methods, including those discussed in this document and any other method that may not be considered here. What is the test duration and how does it compare with a regulatory test under the currently prescribed DOE test method? How much time is needed for control system learning (i.e., adaptation of control parameters in response to “conditioned system” behavior) to take place prior to testing? What specific changes to the facility, including its control systems, are required to conduct load-based testing? Additionally, what are the costs associated with upgrading controls of environmental chambers and the time needed for training technicians to successfully conduct load-based testing?

d. Thermostat Selection and Built-in Control Firmware

A key aspect of system performance addressed by load-based test procedures is the way that the control system impacts the operation and performance of the system. Since thermostats can vary in their control algorithms and how they communicate with a system, the thermostat selection can potentially impact the results of the test (*see* section II.B.2.b of this RFI for further discussion). As noted in section II.B.4.a, CSA EXP07 requires the make and model of the thermostat to be recorded and reported with test data. The 4E IEA Project 2.0 round-robin testing (described in section II.B.4.e of this RFI) is investigating the impact of different thermostat selections on system performance when subjected to the same test procedure using load-based test conditions. DOE is not aware of data showing the variability of test results when pairing the same CAC/CHP model with different thermostats. However, as explained in section II.B.1, in response to a notice of proposed rulemaking ("NOPR") regarding CAC/HP test procedures published on March 24, 2022 ("March 2022 CAC TP NOPR"), NEEA provided data from a report[35] that showed the seasonal efficiency performance of variable-speed CAC/HPs was highly dependent on the internal firmware of the system. 87 FR 16830.

Issue 6: DOE requests comment on the impact of thermostat selection and the built-in firmware version when testing CAC/HP under their native controls. What range of performance could be measured using different thermostats when testing the same system? How does this vary for staged systems as compared with fully variable-speed systems? How should thermostat pairings and the built-in firmware be considered from a certification standpoint (i.e., should the thermostat used for testing be certified as part of the tested combination)? DOE is also interested in knowing how behavior of CAC/HPs in the field varies depending on the thermostats pairing (*i.e.*, those shipped with the unit versus those obtained from third-party suppliers). DOE would like to know what percentage of thermostats can be updated remotely via firmware upgrades and what percentage can only be updated in the field via service technicians.

e. Use of Different Test Methods for Different Purposes

It is DOE's understanding that some organizations seek to use load-based testing as a tool to evaluate the performance of air conditioning and heat pump systems even as the current regulatory test procedures (*e.g.*, appendix M1) are required for certification of compliance with minimum efficient standards. As noted in section II.B.4.a, CSA EXP07 proposes to use test conditions that differ from the Federal test procedures, which will

[35] The report is titled "Heat Pump and Air Conditioner Efficiency Ratings: Why Metrics Matter", and can be downloaded for free from this link: *neea.org/resources/heat-pump-and-air-conditioner-efficiency-ratings-why-metrics-matter*.

yield different test results, whether or not there might be inefficiencies that CSA EXP07 would capture that conventional test methods do not.

Issue 7: DOE is interested in any existing examples of load-based testing for regulatory purposes or for use in voluntary incentive-based programs. Are there draft examples of how such regulation would be applied, with focus on differences as compared with more conventional test methods (e.g., appendix M1)?

f. Test Conditions for Load-Based Methods

Load-based test procedures for CAC/HPs may sometimes have test conditions that do not align with the DOE test procedure outlined in appendix M1. For example, EXP07 includes more test conditions spanning a wider range of outdoor temperatures than appendix M1. Figure II-1 and Table II-2 show a comparison of the test room conditions used in EXP07 versus the test conditions used in the DOE test procedure appendix M1.

Figure II-1: Comparison of Outdoor Dry-Bulb Temperature Test Conditions between EXP07 and DOE Test Procedure (Appendix M1) for CAC/HPs

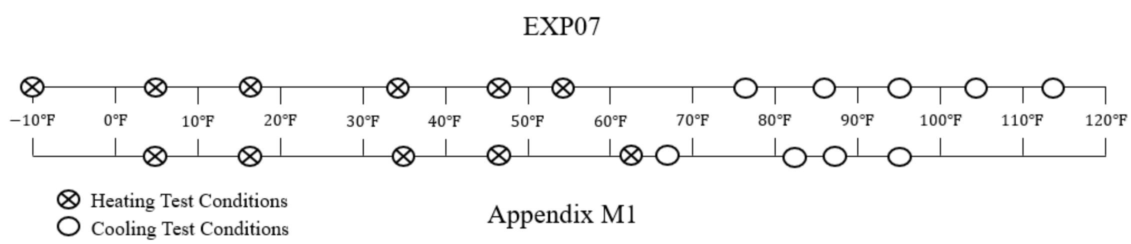

Table II-2: Comparison of Outdoor Dry-Bulb Temperature Test Conditions between EXP07 and DOE Test Procedure (Appendix M1) for CAC/HPs

	Cooling Test Conditions[1]	Heating Test Conditions[2]
Appendix M1	A2 – 95°F Ev – 87°F B1 & B2 – 82°F F1 / G_1* / I_1* – 67°F	$H0_1$ – 62°F $H1_1$ / $H1_2$* / $H1_N$ / $H1C_1$* – 47°F $H2_V$ / $H2_2$* – 35°F $H3_2$ – 17°F $H4_2$* – 5°F
EXP07	CA* - 113°F CB – 104°F CC – 95°F CD – 86°F CE – 77°F	HA* - (-10°F) HB* - 5°F HC – 17°F HD – 34°F HE – 47°F HF – 54°F

* Optional Test Condition
[1] Cooling-mode indoor room test condition temperatures are 80°F dry-bulb, 67°F wet-bulb for appendix M1. EXP07 utilizes different indoor room conditions based on humid climate (74°F dry-bulb, 63°F wet-bulb) and dry climate (79°F dry-bulb, 56°F wet-bulb).
[2] Heating-mode indoor room test condition temperatures are 70°F dry-bulb, 60°F wet-bulb for both appendix M1 and for EXP07.

Issue 8: Given the differences between the EXP07 and appendix M1 test procedures for CAC/HPs, DOE requests information comparing how rankings/ratings of CAC/HPs would differ when tested using the EXP07 test conditions (both outdoor and indoor) rather than the appendix M1 test conditions, keeping other aspects of the test the same. Further, DOE requests comments on the relative benefits and drawbacks of revising the appendix M1 test conditions.

g. Communicating and Non-Communicating Variable-Speed CAC/HP Systems

Controls used with CAC/HPs may transfer information between system components, or they may use more conventional low-voltage on-off signals to indicate "calls" for space conditioning and/or consumer selection of fan settings. In the October 2022 CAC TP Final Rule, DOE defined "communicating control" in the context of variable-speed coil-only CAC/HPs to differentiate the test procedure provisions applicable to communicating systems from those applicable to non-communicating systems. 87 FR 16830, 16837. Section 1.2 of appendix M1 defines "Communicating Variable-Speed Coil-Only Central Air Conditioner or Heat Pump" as follows:

Variable-Speed Communicating Coil-Only Central Air Conditioner or Heat Pump means a variable-speed compressor system having a coil-only indoor unit that is installed with a control system that (a) communicates the difference in space temperature and space setpoint temperature (not a setpoint value inferred from on/off thermostat signals) to the control that sets compressor speed; (b) provides a signal to the indoor fan to set fan speed appropriate for compressor staging and air volume rate; and (c) has installation instructions indicating that the required control system meeting both (a) and (b) must be installed.

Although the DOE test procedure explicitly addresses communicating vs. non-communicating operation only for coil-only variable-speed systems, DOE is aware that there may also be non-communicating blower coil variable-speed system installations. DOE understands that the fundamental differences in the control architecture will lead to performance differences. For example, a non-communicating variable-speed system will not be able to apply classic proportional/integral/differential control algorithms to minimizing space temperature offset from setpoint, since the space thermostat would generally only be able to indicate to the system whether there is a need for conditioning and/or whether a call for a first or a second level of conditioning should be engaged. Thus, it is unclear how such a system would determine the appropriate level of variable-speed compressor operation to engage to meet the conditioning load. It is expected that there would be more variation of the capacity level of such a system, operation which is known to affect efficiency. For communicating variable-speed systems, it is clearer how the control system would be able to set compressor operating level consistent and better optimized for the conditioning need.

DOE is unaware if any of the load-based test methods have different test procedure provisions for communicating and non-communicating CAC/HPs, regardless of whether they are coil-only or blower coil systems.

Issue 9: DOE is interested in test data, if any, that shows how the performance of communicating and non-communicating variable-speed CAC/HPs compares when tested using load-based methods. For systems equipped with non-communicating controls, DOE would like to know how load-based methods address modulation of compressor speed for changing load and outdoor conditions if the difference in indoor space temperature and space setpoint temperature is not communicated to the control setting compressor speed.

h. Load-Based Testing for Single-Stage and Two-Stage Variable-Speed CAC/HP Systems

Much of the discussion about load-based testing has focused on potential performance differences of variable-speed CAC/HP systems in traditional fixed-setting testing as compared with load-based testing methodologies that may better reflect field performance. However, the potential application of load-based testing has also been discussed for single-stage and two-stage CAC/HP systems. Appendix M1 does include cyclic test procedures to capture the losses associated with compressor cycling when capacity is greater than the load.[36] But there may be questions about whether this test is

[36] Sections 3.5 and 3.8 of appendix M1 contain provisions for conducting optional cooling and heating cyclic tests. These cyclic tests are used to determine the Coefficient of Degradation (C_D), which is incorporated into the calculation of SEER2 and HSPF2, to account for any compressor cycling losses. If the optional cyclic tests are not conducted, appendix M1 requires use of the default C_D value of 0.25. However, for the majority of single- and two-stage systems, a lower C_D can be achieved when completing the optional cyclic tests, which results in higher SEER2 and HSPF2.

not sufficiently accurate or whether there are other factors that might cause traditional test methods to provide inaccurate indications of field performance.

Issue 10: DOE requests comment on the application of load-based testing to single-stage and two-stage CAC/HP systems, specifically on the differences between conventional test approaches and load-based testing as indicators of system field performance. Additionally, DOE requests any available information indicating whether the cyclic test methods in appendix M1 may be unrepresentative in capturing cyclic losses. Finally, DOE requests comment on whether there are other aspects of single- and two-stage system operation that are not adequately captured by the test methods of appendix M1.

i. Other Factors that Affect System Energy Use

The overall energy use of CAC/HP systems not only depends on how long they operate in the cooling and/or heating seasons, but also on aspects such as adaptive defrost systems, operation of electric resistance heating elements, operation of the fan when the compressor is not running (*i.e.*, during the shoulder season) and operation of auxiliary components during off-mode, such as crank case heaters. In order to accurately capture the performance of CAC/HP systems while testing in a laboratory for regulatory purposes, it is imperative that a load-based test procedure should also account for the aforementioned aspects.

Issue 11: DOE requests comment on the potential application of load-based test procedure to other aspects of CAC/HP operation affecting energy use, including but not limited to defrost systems, operation of electric resistance heating elements (if equipped), operation of fans when the compressor is not running during the shoulder season, and operation of crank case heaters during off-mode.

C. Stakeholder Requests for Test Improvements in Appendix M1

As noted in section I.B, several stakeholder comments in the October 2022 CAC TP final rule encouraged DOE to review ways to improve the representativeness of the test procedures for CAC/HP in a future rulemaking under DOE's 7-year lookback authority. Stakeholder requests that relate to test procedure improvements in appendix M1 are discussed in the subsequent sections.

1. Shoulder-Season Fan Power Consumption

In their written comments submitted during the rulemaking that culminated in the October 2022 CAC TP final rule, the CA IOUs contended that the current test procedure does not fully reflect energy use during the shoulder-season hours when outdoor temperatures are typically between 55°F and 64°F and the equipment is likely in fan-only mode (*i.e.*, the compressor is not running). (CA IOUs, No. 20 at pp. 2–3) CA IOUs further commented that the HSPF2 metric used for evaluating heating operation in appendix M1 no longer includes fractional bin hours when outdoor temperatures are between 55°F and 64°F and that these hours represent approximately 24 percent of the fractional bin hours relative to appendix M. *Id.*

In the October 2022 CAC TP Final Rule, DOE acknowledged the CA IOUs' comment that shoulder-season fan energy consumption (*i.e.*, fan operation when there is no heating or cooling load) is not captured by either the SEER/SEER2 or HSPF/HSPF2 metrics, which are constructed to represent cooling season efficiency and heating season efficiency, respectively.

DOE notes that a majority of CAC/HPs are installed in the field with a furnace as the air mover (*i.e.*, as coil-only CAC/HPs). Appendix M1 specifies a default fan power for the testing of coil-only CAC/HPs to represent the furnace fan use. The furnace fan test procedure (*see* 10 CFR part 430, subpart B, appendix AA ("appendix AA")) addresses fan energy use for cooling, heating, and constant circulation modes, including constant circulation operation during the shoulder season. Appendix AA uses an estimate of 400 hours as the national-average annual hours of constant circulation fan operation (*see* 10 CFR part 430, subpart B, appendix AA, Table IV.2). The survey data used to develop this estimate value is described in a furnace fan NOPR, published on May 15, 2012. 77 FR 28674, 28682-28683. While the shoulder season may include many hours when heating or cooling is not required, the survey data and DOE's analysis suggest that only 9 percent of systems operate in fan-only mode when no heating or cooling is being provided, indicating that the shoulder-season fan energy consumption may not be as significant as the CA IOUs present. (*See, e.g.*, Table III.1 in the furnace fan NOPR, 77 FR 28674, 28682). While these hours are specifically associated with coil-only CAC/HP systems, they may also be representative of blower coil systems, which are excluded from the scope of appendix AA and covered in appendix M1. Key factors that would make this energy use significant and worth addressing include the constant circulation fan wattage of blower coil systems, the percentage of such systems that use constant fan when not in cooling and heating mode, and the average hours per year operating in this mode for such a system.

Additionally, there is a potential of increased use of constant circulation in systems that employ new refrigerants to mitigate flammability risks. Currently, nearly all CAC/HP products are designed with R-410A as the refrigerant. The EPA Significant New Alternatives Policy ("SNAP") Program evaluates and regulates substitutes for ozone-depleting chemicals (such as CAC/HP refrigerants) that are being phased out under the stratospheric ozone protection provisions of the Clean Air Act. (42 U.S.C. 7401 *et seq*.)[37] Of interest in this RFI, the EPA SNAP Program's list of viable substitutes[38] includes a group of refrigerants classified as A2L refrigerants. A2L refrigerants receive high attention for their low global warming potential in addition to their minimal to zero ozone depletion potential. However, A2L refrigerants also face stricter safety requirements than most due to the flammability concerns associated with their "2L" ASHRAE safety classification[39].

Considering A2L flammability concerns and the large push towards their increased use in design, UL recently published updated safety standards[40] for electrical heat pumps, air-conditioners, and dehumidifiers that include the CAC/HP products at issue in this document. One safety risk these standards address is refrigerant leakage, which can be especially hazardous with A2Ls involved. In satisfaction of new UL safety requirements, manufacturers may need to adjust CAC/HP product design to include refrigerant leak detection systems, which use sensors and control logic to detect a loss of pressure, activate the evaporator fan, and use circulated air to quickly disperse and dilute refrigerant in the event of a leakage. DOE acknowledges that a subsequent need may exist for the constant circulation of refrigerant or circulation based on leak detection to

[37] Additional information regarding EPA's SNAP Program is available online at: *www.epa.gov/ozone/snap/*.
[38] List of EPA SNAP program-approved refrigerant substitutes is available at: *www.epa.gov/snap/substitutes-residential-and-light-commercial-air-conditioning-and-heat-pumps*
[39] ASHRAE assigns safety classification to refrigerants based on toxicity and flammability data. The capital letter designates a toxicity class based on allowable exposure and the numeral denotes flammability. For toxicity, Class A denotes refrigerants of lower toxicity, and Class B denotes refrigerants of higher toxicity. For flammability, class 1 denotes refrigerants that do not propagate a flame when tested as per the standard; class 2 and 2L denotes refrigerants of lower flammability; and class 3, for highly flammable refrigerants such as the hydrocarbons.
[40] On November 1, 2019, UL published an updated 3rd edition of UL 60335-2-40 that includes safety requirements regarding the use A2L refrigerants in CAC/HP product design.

accommodate these refrigerant leak detection and mitigation strategies in CAC/HP product design.

Issue 12: DOE requests information on the typical fan power for constant circulation mode for blower coil systems (or as a fraction of cooling or heating fan power); whether constant circulation mode is a default or user configurable setting for these systems and whether manufacturers plan to modify this as part of their mitigation strategy for refrigerant leakage; and information on the percentage of people that use this mode and the associated hours per year on average the system would be in this mode.

Issue 13: DOE requests comment on whether measurement of SEER2 and/or HSPF2 should take into consideration that a certain fraction of systems will use constant circulation mode rather than turn off the fan during the compressor off mode.

Issue 14: DOE requests comment on whether UL safety requirements for A2L refrigerants will require some level of circulation on a continuous basis, or whether circulation to disperse refrigerant will only be required when sensors detect a leak. DOE is interested to know of any other techniques that manufacturers will use for dispersing the A2L refrigerant in the event of a refrigerant leak.

2. Power Consumption of Auxiliary Components

In comments submitted during the rulemaking that culminated in the October 2022 CAC TP final rule, the CA IOUs also commented that neither the HSPF2 nor the

SEER2 metrics reflect the energy use of auxiliary components, including fans and crankcase heaters, when the compressor is off, and the SEER2 and HSPF2 metrics therefore do not fully represent any difference in the efficiency of auxiliary equipment between systems. (CA IOUs, No. 20 at pp. 2–3) They recommended that DOE consider methods to address these energy uses in a subsequent review of test procedure. *Id.*

DOE notes that there are already test procedures and energy conservation standards governing the allowable off-mode power consumption for CAC/HPs, which encapsulates the off-mode and standby power consumed by auxiliary components such as crankcase heaters as suggested by the CA IOUs. These test procedures are enumerated in section 4.3 of appendix M and appendix M1, and standards are enumerated at 10 CFR 430.32(c)(4). DOE acknowledges the CA IOUs' comment that the energy use of crankcase heaters is not directly included[41] in the SEER2 and HSPF2 metrics but notes that this energy use is accounted for in off-mode power. In a NOPR regarding CAC/HP test procedures published on June 2, 2010 ("June 2010 CAC TP NOPR"), DOE noted that integrating off-mode energy use, and hence crankcase heater energy use, into SEER and HSPF metrics, would not be technically feasible because they both are seasonal descriptors. 75 FR 31224, 31239. Using these two seasonal metrics to account for out-of-season off-mode energy consumption (*i.e.*, the energy consumed during the shoulder season and during the heating season) would be inconsistent with the definitions of SEER and HSPF. *Id.* Hence, in order to maintain the technical integrity of SEER and HSPF and to account for off-mode energy consumption, DOE developed a separate algorithm to calculate the off-mode (off-season) energy consumption[42]. *Id.* Nevertheless, to help

[41] Some energy use associated with crankcase heaters is inherently measured in the cyclic cooling (for non-temperature dependent crankcase heaters) and cyclic heating tests in appendix M1.
[42] The calculation of off-mode power consumption is explained in section 3.13 of appendix M, and section 4.3 of appendix M1.

DOE further assess whether its test procedure adequately addresses crankcase heater energy use, DOE is requesting information and data from stakeholders.

Issue 15: DOE requests information as to what percentage of units on the market (split separately between air-conditioners and heat pumps) are shipped from the factory with crank-case heaters; what percentage have crank-case heaters installed in the field (*e.g.*, by contractors); and the percentage breakdown of controls used with units (both factory- and field-installed) - by those that are energized at full power during the compressor off cycle, those that also have an ambient thermostat to prevent use when temperature is high, and those that are self-regulating.

Issue 16: DOE requests information and available field data, on any other auxiliary components that come equipped with CAC/HPs that use energy or affect system energy use.

In a supplemental notice of proposed rulemaking ("SNOPR") regarding CAC/HP test procedures published on August 24, 2016, DOE revised the off-mode test procedure by imposing time delays to allow self-regulating crankcase heaters to approach equilibrium. 81 FR 58163, 58173-58174 ("August 2016 CAC TP SNOPR"). Specifically, DOE proposed a 4-hour time delay for units without compressor sound blankets and an 8-hour time delay for units with compressor sound blankets. *Id.* DOE proposed these time delays based on testing of a 5-ton residential condensing unit. *Id.* In response to stakeholder comments regarding the aforementioned time delays, DOE decided in the January 2017 CAC TP final rule to adopt the proposed time delays for measurements of off-mode power for units with self-regulating crankcase heaters or heater systems in which the crankcase heater control is affected by the heater's heat, in appendix M1, but not appendix M. 82 FR 1426, 1438. Nevertheless, DOE acknowledges that with more test procedure development time, an approach could potentially be developed that would allow for accurate projections of self-regulating crankcase heater energy use to be determined in reduced time and requests comment on this possibility.

> *Issue 17*: DOE requests test data that would indicate if and how the 4-hour time delay (for compressors without sound blankets) and 8-hour time delay (for compressors with sound blankets) may be reduced, for units with self-regulating crankcase heaters, without compromising the accuracy of the off-mode power consumption measurement.

3. Low-Temperature Heating Performance

In the previous CAC/HP test procedure rulemaking, NYSERDA encouraged DOE to start immediately on foundational work needed to improve the standard and test procedure to better account for equipment performance in cold climates. (NYSERDA, No. 17 at pp. 2–3) NYSERDA requested that DOE make the H4, $H4_2$, or $H4_3$ heating tests in appendix M1 mandatory in order to produce more representative ratings that account for system performance at 5°F. *Id.* NYSERDA also requested that DOE explore how to test and report relative capacity maintenance at temperatures lower than the heating mode test temperatures that are used to determine nominal capacity and suggested that DOE prescribe performance requirements of low-temperature capacity maintenance for products advertised as cold-climate heat pumps. *Id.* Further, NYSERDA requested that DOE evaluate how a variety of sizing approaches could be incorporated into the test procedure. *Id.* NYSERDA highlighted that DOE has previously established that the sizing assumptions inherent in the DOE test procedure are based on cooling capacity and provide an example of a sizing and selection guide that emphasizes heating function. *Id.*

While the H4 heating tests provide meaningful information and more representative ratings for products designed specifically for low temperature operation, appendix M1 includes them as optional tests, as they may not be appropriate for all CHPs. Currently, appendix M1 allows the performance at 5°F to be extrapolated based on tests conducted at 17 ºF and 47 ºF (*i.e.* using the $H3_2$ and $H1_2$ tests, respectively) for CHPs that are not tested at the H4 heating condition. While the ENERGY STAR certification is a voluntary program, DOE notes that the latest ENERGY STAR specification for CAC/HPs[43] already has cold-climate performance and capacity maintenance requirements as suggested by NYSERDA.

In the August 2016 CAC TP SNOPR, DOE noted that most heat pump units in the field are sized based on cooling capacity as opposed to heat pump capacity, consistent with ACCA Manual S provisions. 81 FR 58163, 58188. Subsequently, in the January 2017 CAC TP final rule, DOE revised appendix M1 such that the determination of the heating load line was based on cooling capacity rather than heating capacity. 82 FR 1426,1453-1454. Part of DOE's motivation for this change was that the previous approach of heating load line determination based on the nominal heating capacity (H1N capacity) provided little incentive to design for good heat pump performance, since low H1N capacity resulted in a low load line and generally better HSPF. Sizing based on cooling capacity is consistent with trends for sales distributions of heat pumps, which

[43] Version 6.1 of the ENERGY STAR specification for CAC/HPs, revised in January 2022, can be found here: *www.energystar.gov/products/spec/central_air_conditioner_and_air_source_heat_pump_specification_version_6_0_pd.*

have had greater adoption in milder climates than cold climates[44]. However, DOE is aware that NRCan has proposed alternatives for sizing CAC/HPs, in its "Air Source Heat Pump Sizing and Selection Guide"[45], which provides four different approaches with varying emphasis on heating vs. cooling, ranging from sizing based on cooling to sizing such that the heat pump can meet the design heating load without need for resistance auxiliary heat. DOE acknowledges that in cold climates, sizing a heat pump for heating may be more appropriate than sizing for cooling. Further, DOE acknowledges that accurate information regarding heat pump cold-weather performance is relevant for selection of the best heat pumps for cold climates. Nevertheless, it is not clear how a test procedure using a heating load line based on heating performance would incentivize good heating performance, particularly if it is based on heating performance at 47 ºF, which is not a heating design temperature. As mentioned earlier, this is the same issue that led DOE to move to the cooling-capacity-based load line in appendix M1. Further, given the greater market share in milder climates, it is unclear that requiring a 5 ºF test is appropriate for all heat pump models.

Issue 18: DOE requests comment on whether it would be appropriate to make the H4 heating tests mandatory for all CHPs. If not for all CHPs, DOE requests comment on whether it would be appropriate to make the tests mandatory for any subset of CHPs, *e.g.,* cold climate heat pumps, and if so, what characteristics would represent a clear delineation to distinguish such models from others. DOE

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[44] RECS 2020 data shows that electric heat pumps represent 29% of primary space heating equipment in homes in the South region, which is a higher number as compared to the 14% for US overall. *See*: *www.eia.gov/consumption/residential/data/2020/hc/pdf/HC%206.8.pdf*

[45] The "Air Source Heat Pump Sizing and Selection Guide" was written by NRCan in response to stakeholder requests for consistent guidance for sizing ASHPs according to the design heating or cooling load and intended use as well as identifying the appropriate system according to the installation and application. The four methods of sizing in the Guide are Options 4A (Emphasis on Cooling), 4B (Balanced Heating and Cooling), 4C (Emphasis on Heating) and 4D (Sized on Design Heating Load). The "Air Source Heat Pump Sizing and Selection Guide" is available here: *publications.gc.ca/collections/collection_2021/rncan-nrcan/M154-138-2020-eng.pdf.*

also seeks information on the prevalence of test chambers capable of testing CHPs at outdoor ambient temperature of 5°F.

Issue 19: Further, DOE requests comment on whether the test procedure for such cold climate heat pumps should use a heating load line based on heating performance, and how such an approach could be implemented such that it does not weaken the incentive for good cold-temperature heating performance.

D. Additional Improvements in Appendix M1

In addition to the potential improvements in appendix M1 suggested by stakeholders in previous rulemakings, DOE is also considering potential improvements to address issues and questions that have come to light as part of DOE testing of CAC/HPs, industry technical committee discussions, and other discussions with stakeholders.

1. Impact of Defrost on Performance

Defrost is required for heat pumps when operating in moderate to low outdoor temperatures when the outdoor coil surface temperature is sufficiently low to freeze moisture removed from the air or precipitation that can collect on the coil. For defrost, the system switches back to cooling mode operation in which heat is transferred from the indoor coil to the outdoor coil to provide the heat to warm the coil and melt the frost. During defrost, different control strategies are applied to maintain comfort level inside the house. For example, the indoor fan may or may not be operated during defrost, and (if the indoor fan is operated) the auxiliary resistance heater may or may not be energized to warm the indoor air while the system is temporarily in defrost mode. Defrost initiation can be based on time (clock time or time of compressor operation), or the need for defrost can be determined based on temperature and pressure or other measurements that provide an indication of the need for defrost.[46] Appendix M1 defines a demand-defrost control system as a system that defrosts the heat pump outdoor coil only when measuring a predetermined degradation of performance. When frequent defrost occurrences are not needed, *e.g*. when there is insufficient moisture in the outdoor air to build up a significant frost layer on the outdoor coil, demand defrost can save energy by delaying defrost initiation. Defrost cycles are terminated when there is indication that defrost has been long enough for frost to be eliminated from the coil, *e.g.,* when a coil temperature sensor indicates the coil is well above 32 ºF.

For CAC/HPs equipped with demand defrost, appendix M1 includes a term called the demand defrost credit ("F_{def}") in the HSPF2 calculation to provide nominal credit for heat pumps with a demand-defrost control system, reflecting the relative improvement in heating mode efficiency due to use of demand defrost rather than defrosts with fixed periodicity. The demand-defrost credit, first introduced in a March 14, 1988, rulemaking (53 FR 8304, 8319), is calculated by the following equation in section 3.9.2 of appendix M1: $F_{def} = 1 + 0.03[1 - \frac{\Delta\tau_{def} - 1.5}{\Delta\tau_{max} - 1.5}]$, where $\Delta\tau_{def}$= time between defrost terminations (in hours) or 1.5, whichever is greater. $\Delta\tau_{def}$ is assigned a value of 6 if this limit is reached during a frost accumulation test and the heat pump has not completed a defrost cycle, and $\Delta\tau_{max}$= maximum time between defrosts as allowed by the controls (in hours) or 12, whichever is less, as provided in the certification report.

The credit equation has remained unchanged in its current form in the test procedure since at least January 22, 2001, when DOE published a NOPR. 66 FR 6767. Based on the test results of several CAC/HPs in various programs, DOE has noticed a

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[46] Some examples of parameters monitored for demand-defrost control systems are coil to air differential temperature, coil differential air pressure, outdoor fan power or current, optical sensors. Note that systems that vary defrost intervals according to outdoor dry-bulb temperature are not demand-defrost systems.

range of defrost operation sequences and a range of approaches to defrost initiation for demand defrost. Based on these observations, DOE acknowledges that the demand defrost credit may no longer accurately reflect the benefits of demand defrost.

> *Issue 20*: DOE seeks information on the operation of demand-defrost control systems, specifically information that would indicate whether the demand-defrost credit outlined in the calculation in section 3.9.2 of appendix M1 is representative of the improvement in seasonal heating efficiency in field operation. Further, DOE requests comment whether any specific change in the credit equation could improve its accuracy.

Appendix M1 requires that CHPs undergo a test at 35 ºF dry-bulb temperature and 33 ºF wet-bulb temperature, a condition for which frost accumulation is rapid, generally affecting performance before a 30-minute steady-state test can be completed. For this condition, the test procedure prescribes use of a transient test, including a frost accumulation period followed by defrost. Capacity and power input for the test are averaged for a full cycle of heating followed by defrost. At this condition, appendix M1 estimates the average capacity is 10 percent lower (or more) than it would be if there were no frost accumulation, while average power may be just slightly lower, thus reducing efficiency. At temperatures between 17 ºF and 45 ºF, the performance calculations prescribed in the test procedure call for representing capacity as a linear function of temperature based on the tests conducted at 17 ºF and 35 ºF—likewise for power input. Hence, the frost/defrost impact is built into the HSPF2 calculation for temperatures in this range. The DOE test procedure requires use of the 35 ºF test for single-stage and two-stage CHPs for all capacity levels. However, for variable-speed CHPs, the test procedure requires the defrost test be conducted only at intermediate compressor speed, and performance is estimated using default degradation factors at full capacity (*see* section 3.6.4.1.c of appendix M1).

In testing, DOE has observed variations among CHP models in regard to defrost control (*e.g.*, time durations of the defrost can vary significantly for different models, and the indoor unit fan shuts off during defrost for some units but not all). In addition, as part of the DOE CCHP Tech Challenge, DOE has tested systems with electric resistance heaters and noted that resistance heater operation during defrost can vary significantly for different models. This varying behavior clearly affects energy use, and while some aspects of which may be captured by the current appendix M1 test procedure, others may not be.

> *Issue 21*: DOE requests information regarding defrost impact on heating capacity and power input over a range of temperatures to inform evaluation of whether the approach used in the DOE test procedure to account for this impact is accurate or whether it could be improved by revision.

2. Inlet Duct Design for Accurate Measurement with Minimal Length

In a final rule regarding CAC/HP test procedures published on June 8, 2016 ("June 2016 CAC TP final rule"), DOE made clarifications on the indoor unit air inlet geometry and made a revision to ensure that the inlet plenum is not installed upstream of the airflow prevention device, and that the minimum lengths of inlet plenum, locations of static-pressure taps, and minimum cross-sectional dimensions are consistent with American National Standards Institute ("ANSI")/ASHRAE Standard 37-2009 ("ANSI/ASHRAE 37-2009"), Methods of Testing for Rating Electrically Driven Unitary Air-Conditioning and Heat Pump Equipment. 81 FR 36991, 37037. DOE also clarified that when an inlet plenum is not used, then the length of straight duct upstream of the unit's inlet within the airflow prevention device must still adhere to the inlet plenum length requirements as illustrated in ANSI/ASHRAE 37-2009, figures 7b, 7c, and 8. *Id*.

In response, AHRI and Nortek commented that DOE's clarification of inlet plenum may result in the overall height of unit setup exceeding the current height limit of many existing psychrometric rooms. 82 FR 1426, 1463. They proposed that DOE should consider allowing the approach included in ASHRAE's RP 1581, requesting DOE to approve the use of the 6" skirt coupled with the 90° square vane elbow, along with the appropriate leaving duct. *Id.* At the time of the January 2017 CAC TP Final Rule, the ASHRAE Standards Policy Committee had not added the details of RP 1581 into ASHRAE Standard 37, and hence DOE did not modify its requirement laid out in the January 2016 CAC TP Final Rule. However, DOE is aware that these details may be part of the upcoming edition of ASHRAE Standard 37.

> *Issue 22:* DOE seeks test data that shows testing done using reduced overall height of the unit setup (similar to that proposed in ASHRAE RP 1581) and compared against the baseline duct designs in ASHRAE 37-2009 Figures 7(b) and 7(c) for blower coil indoor units, and Figure 8 for coil-only indoor units. DOE requests information that could help inform the existing CAC/HP test procedures to allow testing in smaller environmental chambers, or to incorporate adjustments to the test setup that might reduce test burden.

3. Heat Comfort Controllers

A heat comfort controller enables a heat pump to regulate the operation of the electric resistance elements such that the air temperature leaving the indoor section does not fall below a specified temperature (*see* appendix M1). Appendix M1 notes that heat pumps that actively regulate the rate of electric resistance heating when the controls indicate heat pump capacity at the given outdoor temperature is insufficient to meet the load (*e.g.*, through higher-stage calls from the thermostat), but do not operate to maintain a minimum delivery temperature, are not considered as having a heat comfort controller.

Section 3.6.5 of appendix M1 includes test instructions for testing heat pumps having a heat comfort controller. However, DOE understands that the heat comfort controller option may no longer be prevalent in contemporary CHP systems.

> *Issue 23*: DOE requests information on the prevalence of CHP systems that include heat comfort controllers. DOE requests feedback on whether the heat comfort controller test approach in appendix M1 is utilized by manufacturers, and if yes, whether it needs to be updated.

4. Cut-out and Cut-in Temperature Certification

The calculation of HSPF2 in appendix M1 requires values for cut-out[47] and cut-in[48] temperatures (s*ee, e.g.*, equation 4.2.1-3 in section 4.2 of appendix M1). For CAC/HPs that do not include the cut-out and cut-in temperatures in their installation manuals, the manufacturer (or DOE, in case of compliance testing) must provide the test lab with this information. DOE's lab testing suggests that manufacturers often use cut-out and cut-in temperatures in their HSPF2 calculations that are much lower than can be reasonably expected in the field—in some instances as low as -40°F. However, a review

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[47] Cut-out temperature refers to the outdoor temperature at which the unit compressor stops (cuts out) operation

[48] Cut-out temperature refers to the outdoor temperature at which the unit compressor stops (cuts out) operation.

of product literature for scroll compressors with model numbers Copeland ZP*3KE and ZP*5KE R410A (typically used in CAC/HPs) shows that the lowest refrigerant evaporating temperature of these systems is no lower than -10°F[49].

DOE has also found in testing that the ambient temperatures at which the control cuts out and cuts in may be significantly different than the control's specified temperatures. This can be due to control component manufacturing variation. However, it can also be due to sensors being located where temperature deviates from that of the ambient air—this can occur downstream of the outdoor coil, which absorbs heat from the ambient air during heat pump operation.

> *Issue 24*: DOE requests information on the range of cut-out temperatures for compressor operation of CAC/HPs.

5. Extending the Definition of Low-static Blower-Coil Systems to Single-split Systems

Section 3.1.4.1.1 of appendix M1 defines the minimum external static pressure ("ESP") for ducted blower coil systems in Table 4. For conventional blower coil systems (*i.e.*, all CAC/HPs that are not classified as ceiling-mount, wall-mount, mobile home, low-static, mid-static, small-duct high-velocity ("SDHV"), or space-constrained), the minimum ESP is specified as 0.5 inches of water column ("w.c."). The definition for low-static blower-coil systems includes only multi-split and multi-head mini-split systems—it does not include single-split systems. In response to the March 2022 CAC TP NOPR, DOE received multiple comments concerning the 0.5 inches w.c. minimum

[49] Figure 7 in the operating bulletin of the Copeland ZP*3KE and ZP*5KE R410A scroll compressors shows their evaporating envelope, clearly indicating that they should not be used below saturated suction temperatures of -10°F, implying that this should be set as the cut-out temperature. The bulletin is available here *climate.emerson.com/documents/ae-1331-zp16-to-zp44k3e-zp14-to-zp61k5e-r-410a-1-5-to-5-ton-copeland-scroll-compressors-en-us-1571048.pdf*

ESP. AHRI and Samsung commented that currently, appendix M1 does not allow testing of low-static single-zone[50] units and requested that the low-static blower coil system definition be expanded to include products that cannot accommodate the 0.5 inches w.c. necessary for testing. (AHRI, No.25 at p. 7, Samsung, No.22 at pp. 2–3)

In the October 2022 CAC TP final rule, DOE did not revise the definition for low-static blower coil systems, nor did it include any new test provisions to accommodate these system types. DOE presented evidence from the November 2015 SNOPR (80 FR 74020, 69355), 2016 CAC Term Sheet (*see* 2016 CAC Term Sheet: Docket No. EERE–2014–BT–STD–0048, No. 76), and the August 2016 CAC TP SNOPR (81 FR 58163) public meeting[51] to indicate that stakeholders had rejected DOE's proposal to establish a "short-ducted" product class, and a majority of them expressed support for the new minimum ESP requirements that DOE had proposed, including the 0.5 inches w.c. ESP requirement generally applicable to single-split systems. Thus, DOE believed that revising the definition of low-static blower coil systems, as suggested by Samsung and AHRI, would conflict with the intent of the stakeholders' comments when establishing appendix M1, and could potentially create an unfair competitive advantage for such systems by allowing more lenient testing conditions (and thus comparatively higher ratings) as compared to conventional centrally ducted systems tested at minimum ESPs exceeding 0.50 inches w.c. Rather than granting test procedure waivers to allow such models to test using lower ESP, DOE considers it more appropriate to revisit the issue in a test procedure rulemaking. Thus, DOE is soliciting feedback on this issue.

[50] The comments used the term "single-zone", which is addressed by the term "single-split" in appendix M1.

[51] *See www.regulations.gov* Docket No. EERE-2016-BT-TP-0029, No. 20 for the transcript of the August 2016 CAC TP SNOPR public meeting.

Issue 25: DOE requests comment from stakeholders on whether the low-static blower-coil system definition should be extended to single-split systems, and if extended, how these low-static blower-coil systems will be differentiated from conventional systems.

6. Hybrid Heat Pumps

Heat pumps generally perform less efficiently at low ambient outdoor temperatures than they do at moderate ambient outdoor temperatures. DOE is aware of CHPs that combine the operation of a conventional electric CHP with a back-up heating source, such as a fuel-fired furnace or boiler. These are referred to as "dual-fuel" or hybrid heat pumps ("HHPs") and provide an alternative to heat pumps specifically designed to perform in cold climates (*i.e.*, cold climate heat pumps). HHPs rely on heat pump operation at milder ambient temperatures, but switch to the back-up heating source at low ambient temperatures, thereby optimizing for energy cost and comfort.

Currently, the HSPF2 calculation at appendix M1 does not differ for a HHP and heat pumps that rely solely on vapor-compression or electric resistance auxiliary heating. However, this may not be representative of HHP field operation since the back-up heating source takes over for much of the coldest conditions when heat pump efficiency would be lower. While the focus of test procedures for cold climate heat pumps has been on evaluation of performance at colder temperatures (*e.g.* the optional 5 ºF test condition) to incentivize improved cold-temperature performance, incentivizing efficiency improvement for HHPs might more appropriately focus on warmer conditions, potentially temperatures warmer than 17 ºF.

Issue 26: DOE requests information on the prevalence of HHP systems (including shipment numbers and shipment breakdown among single-stage, two-stage and variable-capacity) and the climates they are most used in. DOE requests information on how the controls for HHPs are generally set up to provide dual functionality – specifically, whether the furnace is just set at a higher stage, or whether there is a crossover temperature below which the CHP isn't used, if so, the range of crossover temperatures; and whether these systems have electric resistance auxiliary heaters. DOE requests feedback on whether it is more appropriate to adjust the HSPF2 to address actual operation of the heat pump or just to emphasize performance only in heat pump mode (*i.e.*, when the back-up source is not operating).

III. Submission of Comments

DOE invites all interested parties to submit in writing by the date specified under the **DATES** heading, comments and information on matters addressed in this RFI and on other matters relevant to DOE's consideration of amended test procedures for CAC/HPs. These comments and information will aid in the development of a test procedure NOPR for CAC/HPs if DOE determines that amended test procedures may be appropriate for these products.

Submitting comments via www.regulations.gov. The *www.regulations.gov* web page will require you to provide your name and contact information. Your contact information will be viewable to DOE Building Technologies staff only. Your contact information will not be publicly viewable except for your first and last names, organization name (if any), and submitter representative name (if any). If your comment is not processed properly because of technical difficulties, DOE will use this information to contact you. If DOE cannot read your comment due to technical difficulties and cannot contact you for clarification, DOE may not be able to consider your comment.

However, your contact information will be publicly viewable if you include it in the comment or in any documents attached to your comment. Any information that you do not want to be publicly viewable should not be included in your comment, nor in any document attached to your comment. Following this instruction, persons viewing comments will see only first and last names, organization names, correspondence containing comments, and any documents submitted with the comments.

Do not submit to *www.regulations.gov* information for which disclosure is restricted by statute, such as trade secrets and commercial or financial information (hereinafter referred to as Confidential Business Information ("CBI")). Comments submitted through *www.regulations.gov* cannot be claimed as CBI. Comments received through the website will waive any CBI claims for the information submitted. For information on submitting CBI, see the Confidential Business Information section.

DOE processes submissions made through *www.regulations.gov* before posting. Normally, comments will be posted within a few days of being submitted. However, if large volumes of comments are being processed simultaneously, your comment may not be viewable for up to several weeks. Please keep the comment tracking number that *www.regulations.gov* provides after you have successfully uploaded your comment.

Submitting comments via email, hand delivery/courier, or postal mail. Comments and documents submitted via email, hand delivery/courier, or postal mail also will be posted to *www.regulations.gov*. If you do not want your personal contact information to be publicly viewable, do not include it in your comment or any accompanying documents. Instead, provide your contact information on a cover letter. Include your first and last names, email address, telephone number, and optional mailing address. The cover letter will not be publicly viewable as long as it does not include any comments.

Include contact information each time you submit comments, data, documents, and other information to DOE. If you submit via postal mail or hand delivery/courier, please provide all items on a CD, if feasible, in which case it is not necessary to submit printed copies. Faxes will not be accepted.

Comments, data, and other information submitted to DOE electronically should be provided in PDF (preferred), Microsoft Word or Excel, WordPerfect, or text (ASCII) file format. Provide documents that are not secured, written in English and free of any defects or viruses. Documents should not contain special characters or any form of encryption and, if possible, they should carry the electronic signature of the author.

Campaign form letters. Please submit campaign form letters by the originating organization in batches of between 50 to 500 form letters per PDF or as one form letter with a list of supporters' names compiled into one or more PDFs. This reduces comment processing and posting time.

Confidential Business Information. According to 10 CFR 1004.11, any person submitting information that he or she believes to be confidential and exempt by law from public disclosure should submit via email two well-marked copies: one copy of the document marked confidential including all the information believed to be confidential, and one copy of the document marked "non-confidential" with the information believed to be confidential deleted. DOE will make its own determination about the confidential status of the information and treat it according to its determination.

It is DOE's policy that all comments may be included in the public docket, without change and as received, including any personal information provided in the comments (except information deemed to be exempt from public disclosure).

DOE considers public participation to be a very important part of the process for developing test procedures and energy conservation standards. DOE actively encourages the participation and interaction of the public during the comment period in each stage of this process. Interactions with and between members of the public provide a balanced discussion of the issues and assist DOE in the process. Anyone who wishes to be added to the DOE mailing list to receive future notices and information about this process should contact Appliance and Equipment Standards Program staff at (202) 287-1445 or via e-mail at *ApplianceStandardsQuestions@ee.doe.gov*.

Signing Authority

This document of the Department of Energy was signed on January 12, 2023, by Francisco Alejandro Moreno, Acting Assistant Secretary for Energy Efficiency and Renewable Energy, pursuant to delegated authority from the Secretary of Energy. That document with the original signature and date is maintained by DOE. For administrative purposes only, and in compliance with requirements of the Office of the Federal Register, the undersigned DOE Federal Register Liaison Officer has been authorized to sign and submit the document in electronic format for publication, as an official document of the Department of Energy. This administrative process in no way alters the legal effect of this document upon publication in the *Federal Register*.

Signed in Washington, D.C., on January 12, 2023.

Treena V. Garrett
Federal Register Liaison Officer,
U.S. Department of Energy

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