EXP07:19 Plain Language Guide

A simplified description for non-technical audiences

Introduction

In 2015 the Canadian Standards Association (CSA) formed a standards development work group charged with developing draft test and rating procedures that would better represent in-field performance of VCHPs. This work was co-chaired by Gary Hamer of BC Hydro, Marshall Hunt of Pacific Gas & Electric, and Rob Andrushuk of Manitoba Hydro. Initial lab research was led by Robert Davis at the PG&E lab and by Dr. Jim Braun and his team at Herrick Labs at Purdue University, and was funded by NEEA, NRCan, and PG&E. After several years of lab and committee work, the Canadian Standards Association (CSA) published a technical review version of EXP-07:19, *Load-based and climate-specific testing and rating procedures for heat pumps and air conditioners,* on March 29th, 2019 (referred to simply as *EXP07*).

The purpose of this guide is to provide a plain-language summary description of EXP07. While EXP07 is a highly detailed engineering procedure, this description is intended for people with minimal awareness of engineering concepts such as heat production or removal, measurement of heat and energy, and numeric representations of efficiency. It is intended to foster a better understanding of the test procedure itself, how it works, and how it differs from more traditional test and rating approaches. Readers who want more detailed technical information may refer to the procedure directly, however this guide may serve as a brief introduction that may be useful to those readers. This guide does not cover the history or purposes of EXP07 in any detail, nor does it provide a description of each section of the procedure. It does provide an overview of how load-based testing works, and generally explains the broad concept behind the EXP07 rating procedure.

Load-based Testing

Most fundamental to EXP07 is that, unlike standard lab tests for residential heat pumps and air conditioners (such as *AHRI 210/240*[i]), EXP07 uses a dynamic, load-based approach that measures a system's performance across a wide range of outdoor temperatures, while meeting heating and cooling requirements that are typical for residential applications, using its own thermostat and internal control logic. In this way, the lab environment during the test process is as close to a real-life installation in a house as it can be, while still being carefully controlled so that each test can be both consistent in its results, and provide fair performance comparisons between different models.

In the load-based test, as in a standard rating test, there is an "outdoor room" where the outdoor unit is placed, with highly-controlled conditions that represent the various outdoor temperature and humidity conditions at which the unit is to be tested. The laboratory setup of the outdoor room has *reconditioning equipment*[ii] that is controlled by computer software to maintain those conditions for the duration of each test condition.

In both test approaches, there is also an "indoor room", where the indoor unit is installed. But the way the indoor room is controlled is the key to understanding the load-based test. In a standard lab test, the indoor room (like the outdoor room) is set at a fixed condition of temperature and humidity for each test condition, controlled by the indoor room reconditioning equipment. The unit under test[iii] is set to run in in a steady-state, continuous mode that is defined by the particular test condition. The indoor room reconditioning system is actually responsible for maintaining the indoor room conditions, in a steady-state manner for the duration of the test. The computer software controlling the test simply measures how much heat the unit under test is producing (in heating mode) or removing (in cooling mode), as well as the energy input and other key parameters for the duration of the test.

By comparison, in a load-based test the computer software controlling the indoor room is programmed to mimic a room or space that would be heated (or cooled) by the unit under test. It senses the amount of heat delivered (or removed) from the indoor test room by the unit under test, and it "knows" what the load is supposed to be, so it updates the indoor room temperature accordingly, every few seconds, simulating an actual load. The unit under test is allowed to sense the room temperature, and respond by turning on or off, or changing its output to match the load, according to its own internal logic: the same logic used in a normal field installation.

For example, Figure 1 shows a simplified example of might happen if, during the test, the unit under test produced no heat at all in the indoor room. The test control software would sense that, and the room would cool off over time – in this theoretical example, it loses 50 degrees over an hour's time. In Figure 2, the unit under test is producing half of the needed heat, so the room temperature drops at half the rate as in Figure 1, losing only 25 degrees.

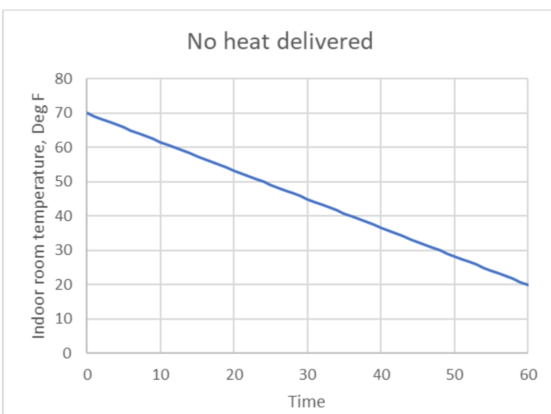


Figure 1: No heat added, temperature drops

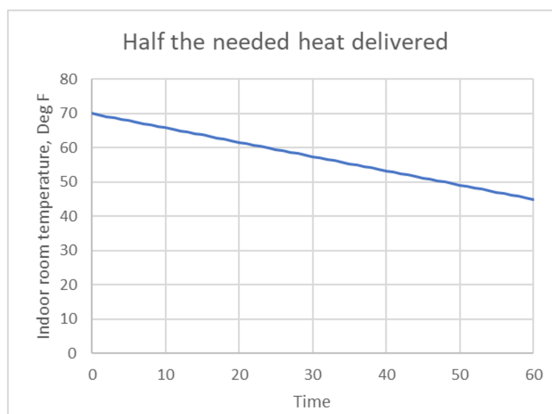
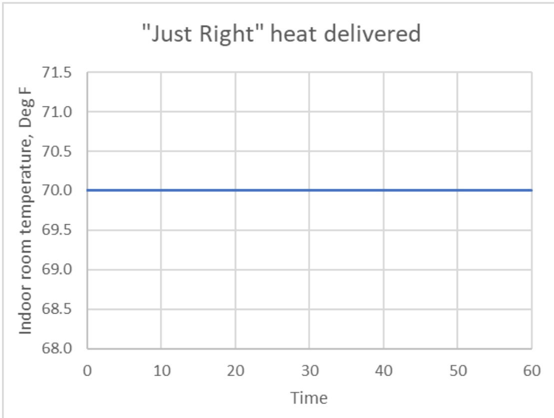


Figure 2: Some heat added, temperature drops more slowly

Figure 3 shows the temperature of the indoor room if the unit under test were generating *exactly* the amount of heat needed to keep up with the load: the temperature stays constant. In theory, the controls of a variable-speed heat pump should operate more or less this way, as long as the imposed load is within the range at which that the unit can operate at the outdoor temperature being used.



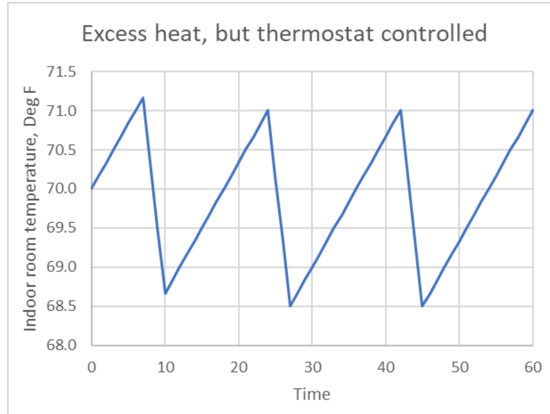


Figure 3: Heat added is correct, stable temperature

Figure 4: Heat added too quickly, temperature controlled by thermostat of tested unit

Figure 4 shows what would typically happen if the heating output was *larger* than the load. Assuming the unit is running at the beginning of the graph, the room temperature will *increase* accordingly. Remember, the indoor room software is keeping track of the heat output of the unit under test, so it “knows” that the unit is producing more heat than needed, and the reconditioning equipment is adjusted so the room temperature goes up. Then, at some point the internal controls *of the unit under test* sense that the room is warm enough, at which point it will shut off (in this case, after 8 minutes). The control software senses this, and the room temperature drops until the internal controls sense that it’s gotten too cool, and turn the unit back on (in this case, at 10 minutes). For this example, the unit only has a little more heating output than needed, so it adds to the indoor temperature more slowly; the temperature drops at a faster rate when it’s off, because that rate depends only on the heating requirement.

Thus, the unit under test is responding to an indoor condition that simulates a heating or cooling requirement. Even though the lab equipment is actually “controlling” the indoor room temperature, it is controlling it based on the response of the tested unit to the changing indoor conditions.

In a real test, of course, the behavior is more complicated. In some cases, variable speed systems can match the heating or cooling requirement closely (such as in Figure 3) but there will naturally be some variation depending on the internal controls. But variable speed systems cannot ramp “down” continuously all the way to “off”; they have a lower limit of heating or cooling output. The test is designed so that for most tested models, the smallest loads used (when outdoor temperatures are mild) will typically be lower than the lowest capacity that the unit can deliver, so that for at least one or two test conditions the response will be somewhat like that in Figure 4. In other cases, when the loads are at their highest (and outdoor temperatures are most extreme), it is expected that tested units will lack the heating or cooling output needed to maintain the steady state indoor temperature target (as in Figure 2). For those test conditions, the unit is set to run “full out” and the remainder of the test is completed keeping the indoor room under steady state conditions. And when conditions are varying for any reason, the test procedure includes detailed instructions so that the lab can determine at what point during a particular test condition the test may be considered “finished” and the lab may move on to the next test condition.

Test Conditions

The EXP07 test procedure uses 11 different heating conditions and 10 different cooling conditions, in total. The tests are run at each condition until the system achieves a stable COP value or reaches the end of the test period. At each outdoor temperature, the amount of heating or cooling that is applied in the dynamic indoor room is appropriate for the outdoor temperature at which the equipment is tested, for a typical residential application. The heating conditions are divided into two general climate areas, Continental and Marine, each with its own sequence of outdoor temperatures and commensurate loads. The cooling test conditions are divided into Humid and Dry climate areas, each with its own sequence. In addition, in the humid cooling tests, a dynamic moisture load is applied by monitoring the removal of humidity by the equipment under test, and then updating the indoor humidity in the test room programming. This works in very much the same way that the dynamic heating and cooling loads are applied to indoor temperature for all of the tests, and it allows the test to measure how well the units remove moisture in the humid cooling tests. Figure 5 shows the four test sequences:

Heating	**Outdoor Conditions**
Continental	6 Temperatures from **-10°F to 54°F**
Marine	4 Temperatures from **17°F to 54°F**
Cooling	**Outdoor Conditions**
Dry	5 Temperatures from **77°F to 113°F**
Humid	4 Temperatures from **77°F to 104°F**

Figure 5: EXP07 Test Sequence Overview

It is worth noting that significant effort has been made to establish consistency in duct conditions and general test and measurement practices with AHRI 210/140, except in cases where such consistency conflicts with the process of load-based tests. In general the laboratory set up, in terms of the methods and materials specified in the measurement of air flows and temperatures, indoor and outdoor room conditions, refrigerant and electrical energy flows, and other necessary so forth are consistent with AHRI 210/140, including (as applicable) the planned updates to AHRI 210/240 (known as “Appendix M1”). Although the indoor unit air flows during all EXP07 tests are allowed to vary based on the internal controls of the unit under test, the initial setup to define and measure full-load air flows, and to establish static pressures for ducted systems, are also harmonized with AHRI 210/240.

Efficiency Metrics

Once the test results have been measured and recorded, seasonal efficiency values are calculated based on the values measured in the tests. The basic method to calculate seasonal efficiencies is consistent with other rating and HVAC[iv] analysis: it is a bin model, that for each climate uses a specific number of hours that are considered to be heating (or cooling) hours at each temperature "bin" throughout the heating and cooling seasons. The temperature "bins" are in increments of 5°F, and the procedure specifies that the unit's heating or cooling output, and energy input, is applied at each bin for the number of hours in that bin.

The assumed heating or cooling needs are the same as those used during the tests. Although there are more temperature bins than test points, the values for each bin can be estimated using the nearest actual test results; this is a typical approach for such a model, and because there are more test points than in other procedures, these estimates are likely to be reasonably representative over a wider range of outdoor conditions. The bin hours used in the model are specific to the 8 climates used in EXP07 (see Figure 6). And for heating, at any outdoor temperatures for which the tested unit does not have enough heating capacity to meet the , the balance of the heating load is assumed to be made up with electric resistance supplemental heaters.

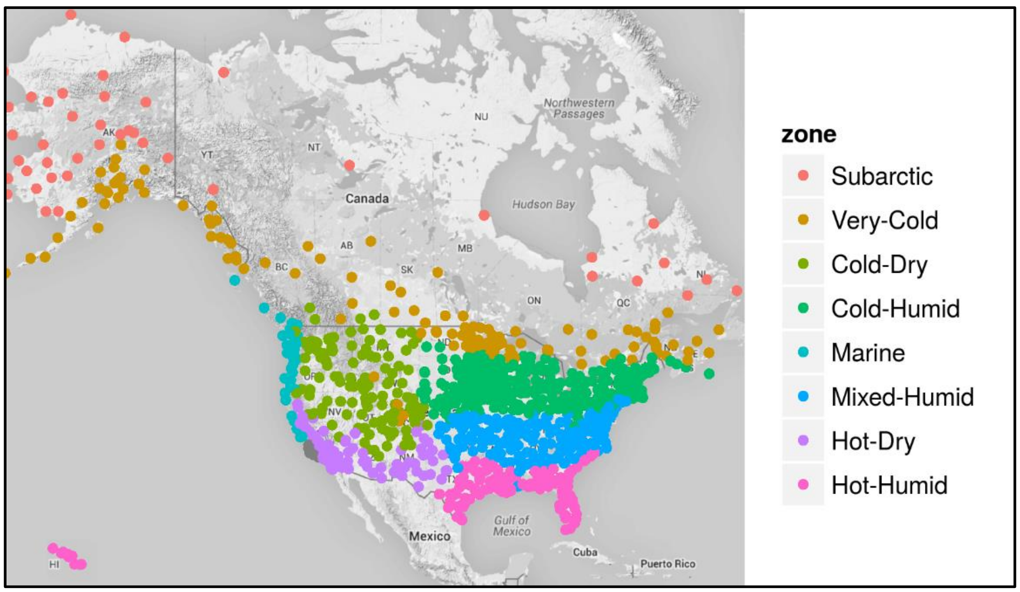


Figure 6: EXP07 Representative Climates

For each climate, the total delivered output is divided by the total electrical input to determine the *Seasonal Coefficient of Performance (SCOP)* for that unit in that climate. The SCOP is a simple ratio, so a COP of 1.0 would represent 100% efficiency (such as electric resistance heat). As one would expect, heating COPs are generally higher in warmer climates and lower in colder climates, and cooling COPs are generally lower in the hottest climates and increase as summer climates get cooler. The eight representative climate zones are shown in Figure 7, along with the test sequence that is used for calculating its heating and cooling SCOPs.

Rating Climate	Heating	Cooling
Subarctic	Standard	*- not used -*
Very Cold	Continental	Humid
Cold/Dry	Continental	Dry
Cold/Humid	Continental	Humid
Marine	Marine	Dry
Mixed	Continental	Humid
Hot/Humid	Continental	Humid
Hot/Dry	Continental	Dry

Figure 7: EXP07 Test results applied to Representative Climates

Finally, there is a provision that the lab test the energy input during certain "standby" modes, for example during the heating or cooling seasons, for temperatures at which there is no heating or cooling requirement, but any HVAC system unit thermostat is likely to be in "heat" or "cool" mode, as well as when the unit controls are turned "off" but the system is still powered on at the circuit panel. The SCOP is reported with the standby power input measured under these conditions factored into the rating, as well as without the standby power factored in.

Application Ratings

In addition to the standard climates and heating and cooling load conditions, Annex F provides alternative rating calculations called "Application ratings" so that users can vary the conditions used in the *model* in a predictable, standardized manner. This could be useful, for example, for a utility incentive program in a region that has a climate that is not a good match for one of the standard representative climates; or for a designer to provide cost-benefit analysis for a specific customer or project. Annex F provides for uses to vary one or more of the following parameters, using the same test data already reported by the lab test:

1. Use a specific climate rather than a generalized climate zone (Annex G provides details of how to develop the bin values based on hourly "normal" climate data).
2. Use a specific equipment load that varies from the one used in the test, for example for a new and superinsulated, or a very old and inefficient, house.
3. For an auxiliary heat source that has a fixed heating output (rather than the variable output assumed for supplemental electric heat in the standard rating model). The auxiliary heat source may be electric resistance, or it may be some other fuel.

For any application rating, details are provided on how such a result needs to be reported so that the application-specific conditions are properly disclosed.

Terminology/References:

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[i] AHRI 210/240 (2017): *Performance Rating of Unitary Air-conditioning & Air-source Heat Pump Equipment (with Addendum 1)*

[ii] Reconditioning equipment – the mechanical equipment that is used to control the test-room conditions to simulate indoor and outdoor spaces.

[iii] Unit Under Test: the specific model of equipment that is being tested for the purpose of efficiency rating .

[iv] HVAC: Heating, Ventilation, and Air Conditioning