Load-based Testing of HVAC Systems

Charlie Stephens
Senior Energy Codes & Standards Engineer

Home Efficiency Forum
October 2018

Canadian Standards Association / CSA Group
Why is this important?

Actual test result

<table>
<thead>
<tr>
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<th>Output</th>
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<tbody>
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210/240 values (approx)

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Projected Usage in kWh vs Previous Period

- This Month
- Last Month
- To date: 68 kWh
- To same day, last month: 90 kWh

Ducted Minisplit, Minute by Minute View for Today

- Yesterday's Usage
- Yesterday's Bedroom #3
- Yesterday's Master Bedroom
- Yesterday's Office
- Yesterday's Bedroom #2
- Yesterday's Master Bath
- Usage
- Bedroom #3
- Master Bedroom
- Office
- Bedroom #2
- Master Bath
- Yesterday's Outdoor Temperature
- Outdoor Temperature

Click and drag in the plot area to zoom in.
Why is this important?
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**Actual test result**

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![Ducted Minisplit, Minute by Minute View for Today](image)

![Average COP vs Ambient Temperature](image)
Harley Residence Heat Pump
Before and after firmware adjustment
An example of why this matters
Conventional DOE/AHRI Testing

- Fixed fan and compressor speeds
  - High fan speeds used in test aren’t available in normal operation
  - Boosts rated efficiencies
- Doesn’t include low-load cycling behavior
- Manufacturer’s reps install equipment and monitor testing using proprietary test modes
  - Can’t be independently duplicated
- Rating extrapolates performance over a wide range of conditions from two test points (with some adjustments)
Stakeholder Needs - Accuracy

- Climate-specific ratings
  - Seasonal heating and cooling performance
- Include standby energy
  - Can be significant during shoulder seasons
- DOE ratings (HSPF/SEER) not consistently representative of actual performance
  - Based on **two data points** (with adjustments), in **one climate**
  - **Savings** based on HSPF **not predictive**
  - Meaningful **performance comparisons impossible**
  - Leads to **modeling inaccuracies**
EXP-07 Development Objectives

- Respond to stakeholder needs:
  - Realistic rating, especially for variable speed systems
  - Seasonal efficiency (heating & cooling) reported for a range of climate zones
  - Detailed data for hourly computer simulation

- Voluntary – not intended as regulation
  - Marketplace differentiation of high-performance products
  - Qualified product lists for market support
Scope

- Single-stage, multi-stage, and variable speed heat pumps and air conditioners
- Residential equipment sizes (<65,000 Btu/hr)
- Ducted/ductless (including central ducted)
- Air-to-air, single-zone
  - Multi-zone and air-to-water planned
- Use dynamic, load based testing rather than lab-induced fixed-speed and fixed-condition, tested under the system’s own controls, as shipped
Task Group

- Working group convened by CSA in 2015
  - Project manager: Jovan Cheema
- Comprised of:
  - Canadian utilities (Chair: Gary Hamer – BC Hydro)
  - Natural Resources Canada (NRCan) / CanMetEnergy
  - Northwest Energy Efficiency Alliance (NEEA)
  - Pacific Gas and Electric (PG&E)
  - Electric Power Research Institute (EPRI)
- Tasked to develop a CSA “Express Document”
  - Not full ANSI process, but similar – standards language
The New Procedures

- Dynamic, load-based testing
- Tested under system’s own controls
- Data reported for all test condition intervals
- 4 sets of tests – 2 for cooling, 2 for heating
- Ratings in 8 climate zones
- Bin hours for weighting not the same as DOE’s
- Application ratings to be included
Extensive Lab Work Involved
Conventional Test Method

Degree F

kBtu/hr
Dynamic Test Method

![Graph showing dynamic test method data. The x-axis represents degrees Fahrenheit (°F) while the y-axis represents kBtu/hr. The graph includes multiple lines and markers indicating test points, max capacity, and COP @Tj.]
Dynamic Load-based Testing

- Indoor room has simulated loads
  - Load is “imposed” by indoor room reconditioning equipment, programmed to mimic load
  - Load varies based on outdoor conditions
  - *Includes dynamic moisture load for humid/cooling*
  - Equipment under test: on-board thermostat/controls govern system operation as normally installed
- Includes native fan, cycling, defrost and latent removal in a single test procedure
- Tested as shipped
Data Reported

Test and report data under a wide range of outdoor conditions and building loads:

- **Cooling:** 5 outdoor room temperatures
  - From 77°F to 113°F (DOE test: 82 & 95)

- **Heating:** 6 outdoor room temperatures
  - From 54°F to -10°F (DOE test: 17 & 47)

- **Report consistent performance data**
  - Can be used in hourly building simulations or design
## Test Conditions

### Cooling

<table>
<thead>
<tr>
<th></th>
<th>Humid Test Conditions</th>
<th>Dry Test Conditions</th>
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<tbody>
<tr>
<td></td>
<td>Outdoor Dry-Bulb</td>
<td>Indoor Dry-Bulb</td>
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<tr>
<td></td>
<td>Temperature, °F</td>
<td>Temperature, °F</td>
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<td>CA¹</td>
<td>N/A</td>
<td>74</td>
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<tr>
<td>CB</td>
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<tr>
<td>CC</td>
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<td>CE</td>
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### Heating

<table>
<thead>
<tr>
<th></th>
<th>Standard Outdoor Conditions</th>
<th>Marine Outdoor Conditions</th>
<th>Indoor Conditions</th>
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<tbody>
<tr>
<td></td>
<td>Dry-Bulb Temperature, °F</td>
<td>Wet-Bulb Temperature, °F</td>
<td>Dry-Bulb Temperature, °F</td>
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CA1: N/A

CB: 104

CC: 95

CD: 86

CE: 77

HA1: -10

HB1: 5

HC: 17

HD: 34

HE: 47

HF: 54

HL¹,²: TOL

TOL: 70

TOL-1: 60 (maximum)
Typical Cooling Test Profile
Performance Data Comparison

- Test COPs match manufacturer engineering data fairly well
  - AHRI shown for illustration purposes (From published values at 17/47; not including defrost, $C_d$)
Climate-based Ratings

- 8 North American climate zones
- Based on (simplified) Building America zones
  - Using a grouping analysis by Ecotope
- Test results used to create bin model for annual performance for each climate
  - Seasonal COPs for heating/cooling in each climate
- With and without standby, crankcase, pan heater
Proposed Climate Zones

- Subarctic
- Very-Cold
- Cold-Dry
- Cold-Humid
- Marine
- Mixed-Humid
- Hot-Dry
- Hot-Humid
Two Sets of Heating & Cooling Tests

<table>
<thead>
<tr>
<th>Rating Climate</th>
<th>Heating</th>
<th>Cooling</th>
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AHRI / DOE Bin Hours (Table 17, p.99)

Note dip in rating zone hours between 32 & 47 F (Zones IV & V – only)
EXP-07 Heating Bin Hours

CSA algorithm eliminates a significant number of “heating” hours above 47 F
EXP-07 Cooling Bin Hours - 6 Climates

CSA algorithm eliminates a significant number of “cooling” hours below 73F
Application Ratings

- Use the same set of lab test data as standardized ratings
- Customizable to specific building types and climates
  - In a way that is consistent with standard ratings
- Includes guidance for realistic use of auxiliary heating (e.g., boiler or electric resistance)
Progress / Next Steps

Lab testing so far:

- PG&E
- Purdue
- NRCan/ CanMetEnergy
  - NGTC
  - UL Plano
- EPRI
- SCE starting

- Many partial; details have varied over time
- Some focused on answering research questions (e.g., simulated loads, repeatability)
Time Line

- Public comments closed December 2017
- Lab testing will continue
  - Several key issues resolved since last winter
  - Controller apparatus & set-up - Purdue to finish summer 2018
- Stable version by fall 2018, for more lab testing and technical feedback
- Publish in late 2018 or early 2019
- Work starting on air-to-water, and multi-split (residential “VRF”) system types
Interested Parties

- Canadian Utilities
- Natural Resources Canada
- Some NE Utilities / State agencies / NEEP
- Northwest Utilities / NEEA
- CA Utilities (PG&E, SCE at least)
- Some cities – decarbonization efforts
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