November 23, 2021

REPORT #E21-325

EXP07 Value Engineering Memo and PowerPoint

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November 5, 2021

Underwriters Laboratory prepared the following memo and PowerPoint deck for NEEA to document how well the 2019 version of the CSA EXP-07 load-based test procedure achieves convergence in the laboratory. Data referred to in this memo was part of lab testing of 15 different heat pumps by UL on behalf of NEEA and Natural Resources Canada (NRCan) during 2020. For additional context, read the initial findings report published by NEEA along with a plain language guide to EXP-07 in July of 2020, "EXP07:19 Load-Based and Climate-Specific Testing and Rating Procedures for Heat Pumps and Air Conditioners[1]."

The objective of this work was to establish a baseline understanding of the 2019 EXP07 test procedure and identify if there are potential opportunities for reducing the test burden without undermining the representative accuracy of the overall rating it develops.

The memo assumes the reader is familiar with the test conditions and acronyms used in the test procedure; however, they are provided for reader convenience:

UUT:	Unit Under Test
NRCan:	Natural Resources Canada
CSA:	Canadian Standards Association
EXP 07:	CSA EXP-07 Test Procedure and Rating – technical review version published in 2019
M1:	AHRI 210/240 Test Procedure and Rating – 2017 version
AHRI:	American Heating and Refrigeration Institute (i.e., the 210/240 test procedure)
Convergence:	The EXP07 condition where the heat pump achieves a stable COP value and that is used to indicate a test cycle is complete.

Next page shows test modes table

[1] https://neea.org/resources/exp0719-load-based-and-climate-specific-testing-and-rating-procedures-for-heat-pumps-and-air-conditioners

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Heating Mode Tables (with test abbreviations)

	Continental outdoor conditions		Marine outdoor conditions		Indoor conditions	
	Dry-bulb temperature, °F	Wet-bulb temperature, °F	Dry-bulb temperature, °F	Wet-bulb temperature, °F	Dry-bulb temperature, °F‡	Wet-bulb temperature,§ °F
HA*	-10	-11.4			70	60 (maximum)
HB*	5	4				
HC	17	14.5	17	15.5		
HD	34	31	34	32		
HE	47	41	47	45		
HF	54	45	54	49		
HL*,†	TOL	TOL-1	TOL	TOL-1		

** Temperatures "HA" (-10°F) and "HB" (5°F) may be omitted for the "Marine", "Hot/Humid", and "Hot/Dry" climate ratings.*

*† TOL as a unique test condition may be omitted if it is lower than -10F, or if it corresponds to one of the other required test temperatures in accordance with footnote *.*

‡ Indoor conditions at start of testing, target for equipment to meet during dynamic test intervals, and indoor room test temperature for full-load test intervals.

Cooling Mode Tables (with test abbreviations)

	Humid test conditions §			Dry test conditions		
	Outdoor dry-bulb temperature, °F	Indoor dry-bulb temperature,† °F	Indoor wet-bulb temperature,‡ °F	Outdoor dry-bulb temperature, °F	Indoor dry-bulb temperature,† °F	Indoor wet-bulb temperature, ‡ °F
CA*	N/A	74	63	113	79	56 (maximum)
CB	104			104		
CC	95			95		
CD	86			86		
CE	77			77		

** Temperature "CA" conditions are required only for a "Hot/Dry" climate rating.*

† Indoor room conditions at start of testing, target for equipment to meet during dynamic test intervals, and indoor room test temperature for full-load test intervals.

‡ Indoor room conditions at start of testing, and indoor room test condition for full-load test intervals.

§ Outdoor wet-bulb temperature during wet coil cooling mode tests where the unit rejects condensate to the outdoor coil shall be selected to maintain an indoor relative humidity of 40%.

Memorandum

August 5, 2021

To: Christopher Dymond, NEEA
From: Mark Baines, UL
Subject: 2020 EXP-07 Analysis and Value Engineering

The Underwriters Laboratory's HVAC/R Performance Test Center in Plano, TX has completed testing of over 20 variable capacity heat pumps to the Canadian Standards Association (CSA) EXP-07 load-based test and rating procedure. The EXP-07 test and rating procedure differs from AHRI 210/240 by measuring performance under loads representative of in-field applications and under the unit's own native controls in order to more accurately characterize real world performance.

Attached is a PPT deck which presents the analysis and findings from test data gathered from a sampling of 15 of the tested units. As per NEEA staff direction, the purpose of this analysis was to better characterize the duration and other test parameters of EXP-07. The overall goal of this work was to begin exploring opportunities for reducing the test burden of EXP-07 without compromising its ability to characterize heat pump performance under loads representative of in-field applications and under its own native control.

The key observations of the work to date are as follows:

- Cooling mode tests converge more quickly than heating tests (average 1.8 h vs 3.1 h, respectively)
- In cooling mode, lower load test interval times show higher standard deviation values than higher load test intervals (suggesting that there's a disparity among manufacturers in their control algorithms in low load situations; some do it better than others)
- Convergence occurring for ALL EXP-07 test intervals, for a given unit, is rare (only 2 of the 15 units converged on all intervals)
- Irregular compressor cycling typically results in non-converging test intervals
    - In cooling mode this occurs during low load test intervals
    - In heating mode this occurs mostly during low load test intervals and when defrost operations occur
- Total 3rd-party lab time required to establish data for rating under AHRI 210/240 and EXP-07 for a single climate is comparable (roughly 60 hours of total lab time – see figure, following page)
    - EXP-07 takes more testing time, but there's less time required for technician interaction with the unit under test (UUT)
    - AHRI 210/240 requires significant break-in time and interaction with the UUT (to dial-in required compressor and fan speeds)
- It may be possible to reduce total test time by 5.8% by reducing convergence time periods from 20 min to 15 min, with a marginal effect to COP
- Reducing max interval time requirements looks promising in cases where a single UUT operating mode occur within each interval

Some of the questions that emerged from this work are:

- Could convergence variability be mostly a function of developmental maturity of the controls rather than test procedure?
- Will future versions of these products have default operating modes that more often result in quicker convergence?
- What is the implication if controls can be updated after the unit has been installed?
- Is there a correlation between overall unit test time (time to convergence) and the repeatability of the seasonal energy efficiency metrics that are determined for the unit?

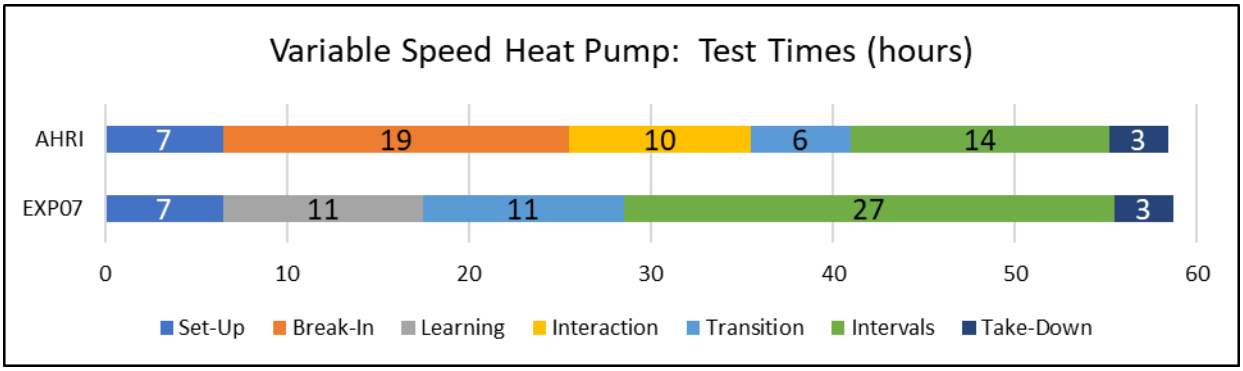
Recommended future work:

- Quantify the impact of automation of the test procedure and removal of non-essential test points
- Evaluate impact of different load lines relative to unit capacity
- Explore load line impacts on COP values measured with EXP-07
- Conduct a field validation of the representativeness of EXP-07 and AHRI 210/240

In Conclusion:

- While the AHRI 210/240 test procedure has shorter in-test time periods, an accurate apples-to-apples comparison to EXP-07 must include the amount of time needed for equipment break in and adjusting unit operating conditions to required full load, static operation.
- There is potential for streamlining the EXP-07 test procedure, reducing overall test burden by 5%-10%.
- The EXP-07 test procedure provides significant additional information not captured by in the AHRI 210/240 test procedure, especially how hardware operates under its own native controls.

A separate PowerPoint document contains graphs and data used to generate this memo. Below is a sample from the PowerPoint document that shows relative time of collecting data for generating a climate specific rating.



CSA EXP07
Value Engineering Assessment

July 2021

General Description

The information herein was developed in 2H2020 and 1H2021 for NEEA. UL used test data from heat pumps tested for NEEA and NRCan in 2019-2020 to establish foundational understanding in preparation of the technical review version of EXP07. The primary objective of this project was to establish baseline values for convergence and test uncertainty that could be used to consider what (if any) elements of the test procedure could be streamlined or what element may provide duplicative or unnecessary data.

Data and values contained within are provided with limited explanation. This presentation is intended for guidance of future work and assist the improvement of EXP07.

Key Observations

- Cooling mode tests converge more quickly than heating tests (average 1.8 h vs 3.1 h, respectively)
- In cooling mode, lower load test interval times show higher standard deviation values than higher load test intervals (suggesting that there's a disparity among manufacturers in their control algorithms in low load situations; some do it better than others)
- Convergence occurring for ALL EXP07 test intervals, for a given unit, is rare (only 2 of the 15 units converged on all intervals)
- Irregular compressor cycling typically results in non-converging test intervals
  - In cooling mode this occurs during low load test intervals
  - In heating mode this occurs mostly during low load test intervals and when defrost operations occur
- Total lab time required to establish data for rating under AHRI 210/240 and EXP07 for a single climate is comparable
  - EXP07 takes more testing time, but there's less time required for technician interaction with the UUT
  - AHRI M1 requires significant break-in time and interaction with the UUT (to dial-in required compressor and fan speeds)
- It may be possible to reduce total test time by 5.8% by reducing convergence time periods from 20 min to 15 min, with a marginal effect to COP
- Reducing max interval time requirements looks promising in cases where a single UUT operating mode occur within each interval

Questions for Consideration

- All units tested were variable capacity machines with microprocessor-based controls. Controls implementation varied significantly between the models tested. It appeared that each manufacturer has their own unique approach. Could convergence variability be mostly a function of developmental maturity of the controls rather than test procedure?
- Units under test were set under default operating modes as shipped and were designed prior to manufacturer awareness of EXP07. Will future versions of these products have default operating modes that more result in quicker convergence? What is the implication if controls can be updated after the unit has been installed?

EXP07 Value Engineering

The goal of the NEEA Value Engineering (VE) project:

To develop specific recommendations to streamline (reduce) the amount of time it takes to conduct EXP07 testing, without affecting the quality of the test results.

Objectives:

1. Develop baselines for:
    A. Test Interval Times (Time to Convergence)
    B. Convergence (how often does it NOT occur? why doesn't it occur?)
    C. Test Burden: AHRI vs EXP07
2. Streamlining Opportunities
    A. Reduce Test Interval Times
        I. Reduce convergence periods from 20 min to 15 min
        II. Reduce 4h (cooling) and 6h (heating) max interval requirements

EXP07 Value Engineering

CONTENTS:

1. Develop baselines for:
   A. Test Interval Times (Time to Convergence)
   B. Convergence (how often does it NOT occur? why doesn't it occur?)
   C. Test Burden: AHRI vs EXP07
2. Streamlining Opportunities
   A. Reduce Test Interval Times
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      II. Reduce 4h (cooling) and 6h (heating) max interval requirements

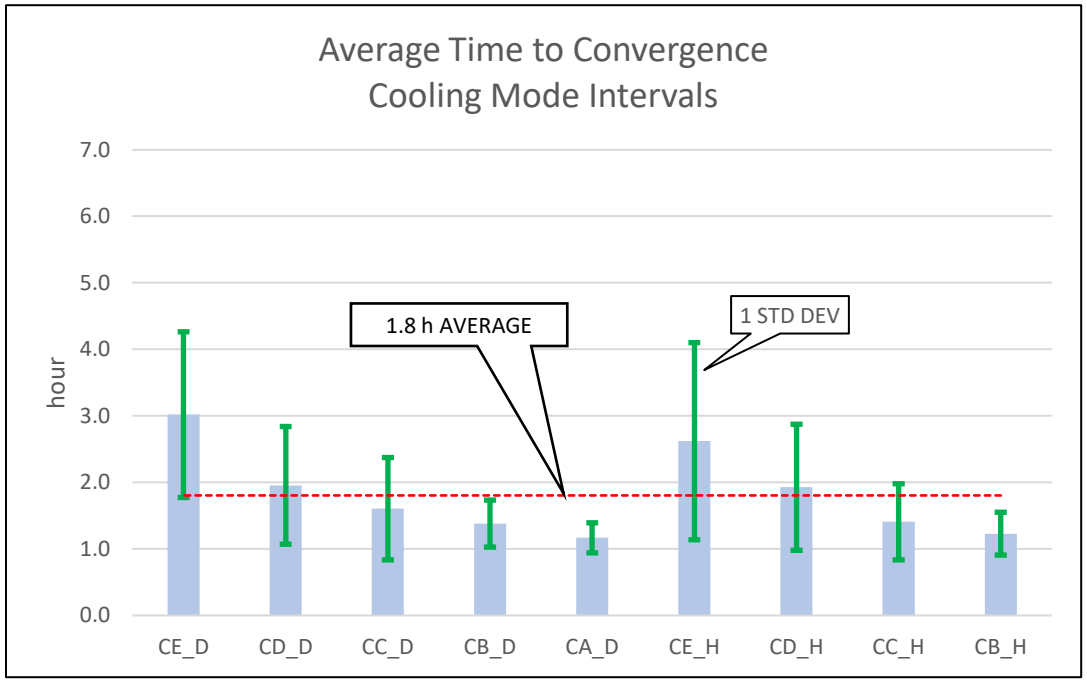
EXP07 Value Engineering

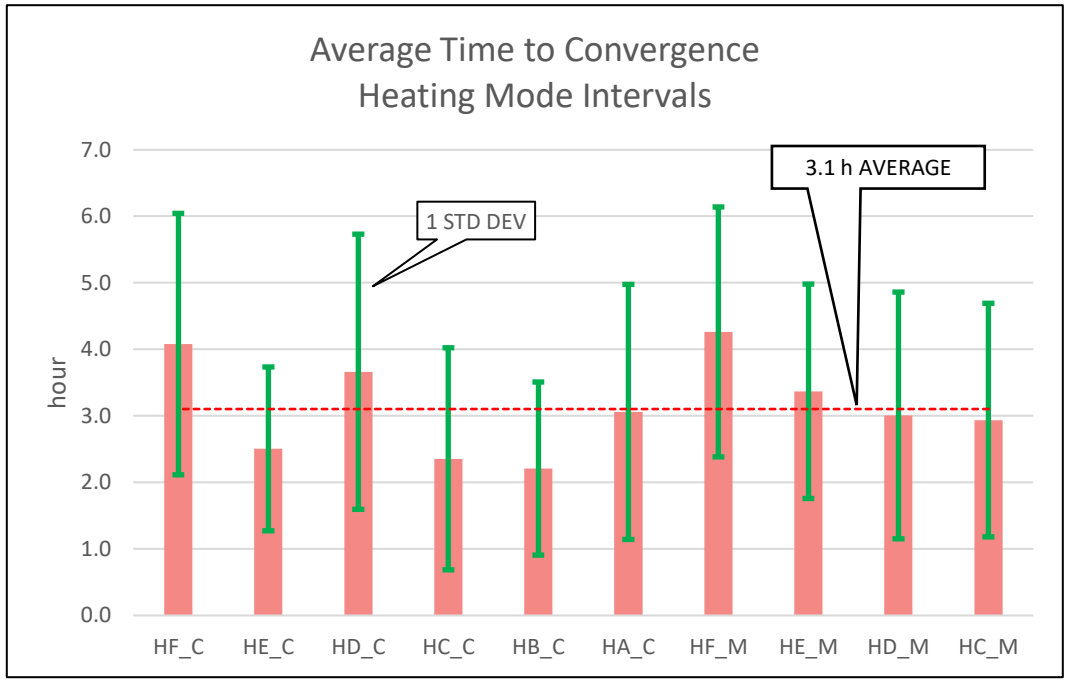
1. Baselines: Test Interval Times – Time to Convergence

- A sample of 15 variable-speed heat pumps that have been tested to the full compliment of EXP07 test intervals were used for this baseline determination
- 12 ductless units, 3 ducted units
- Test interval times are based on the time it takes to run each interval to convergence of COP
  - Test interval times do not include any other test-related times, such as UUT set-up & take-down, transition time between intervals or learning cycles
- Convergence occurs during each test interval when the COP values for two separate and consecutive 20-minute (minimum) periods of time are within 1% of the average COP of the two separate periods
  - Convergence is an indicator of stability of measured data; when convergence occurs, the data contained within the overall convergence period is of a certain stability
  - It takes anywhere from 1 h - 4 h (cooling) or 1 h - 6 h (heating) for convergence to occur
  - If convergence does not occur within 4 h of running a cooling interval or 6 h of running a heating interval, the COP for the interval is based on the entire 4 h or 6 h of data collected within those time frames
- The charts in the next 3 slides provide summaries of the average Test Interval Times for the cooling and heating mode test intervals

EXP07 Value Engineering

1. Baselines: Test Interval Times – Time to Convergence

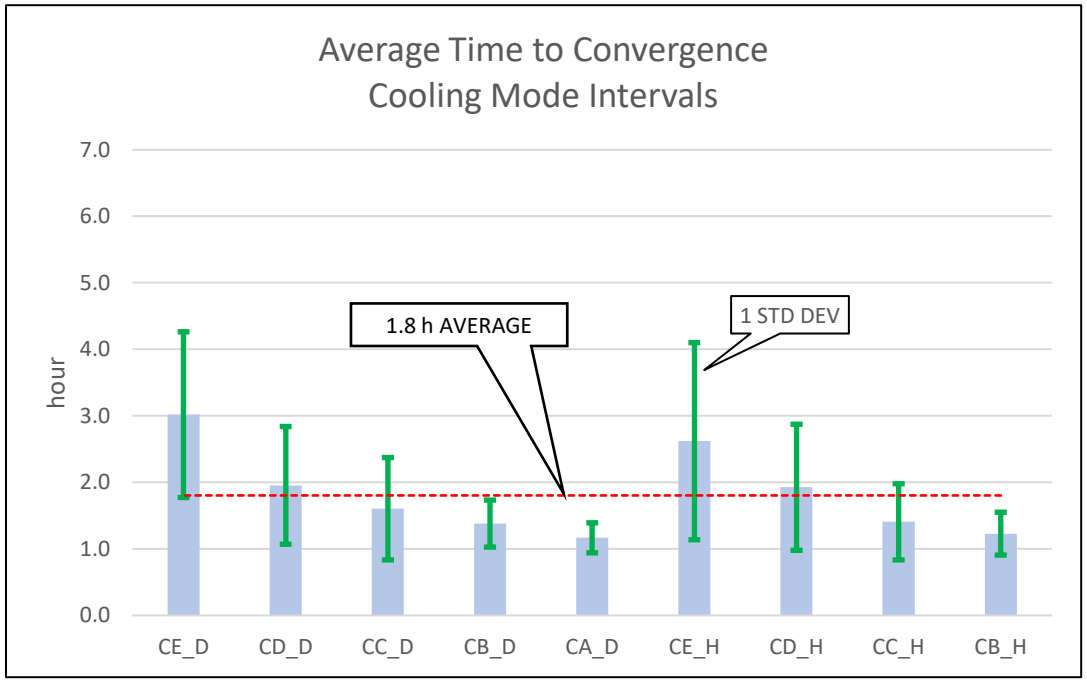


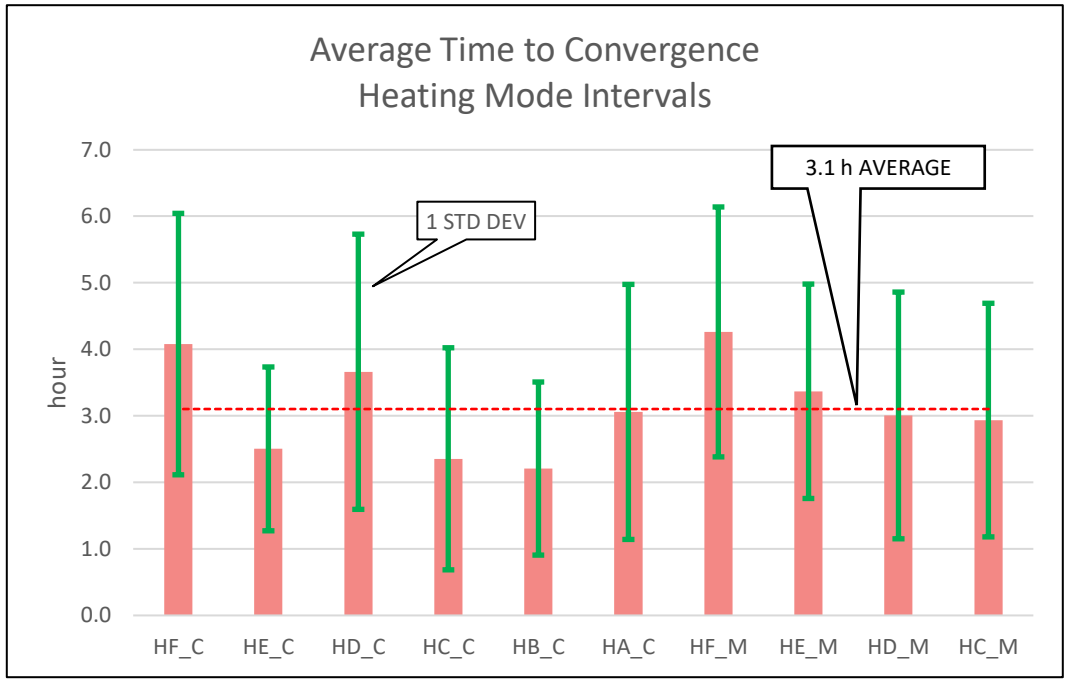


- Individual test intervals are along the horizontal axes; units of hours are along the vertical axes
- Two sets of test intervals are seen for cooling (Dry and Humid) and heating (Continental and Marine)
- Increasing building loads are displayed from left to right; lowest load on the left, highest load on the right (of each set)
- The average cooling and heating test interval times are shown with red-dotted lines
- One standard deviation is shown with green horizontal lines for each test interval

EXP07 Value Engineering

1. Baselines: Test Interval Times – Time to Convergence



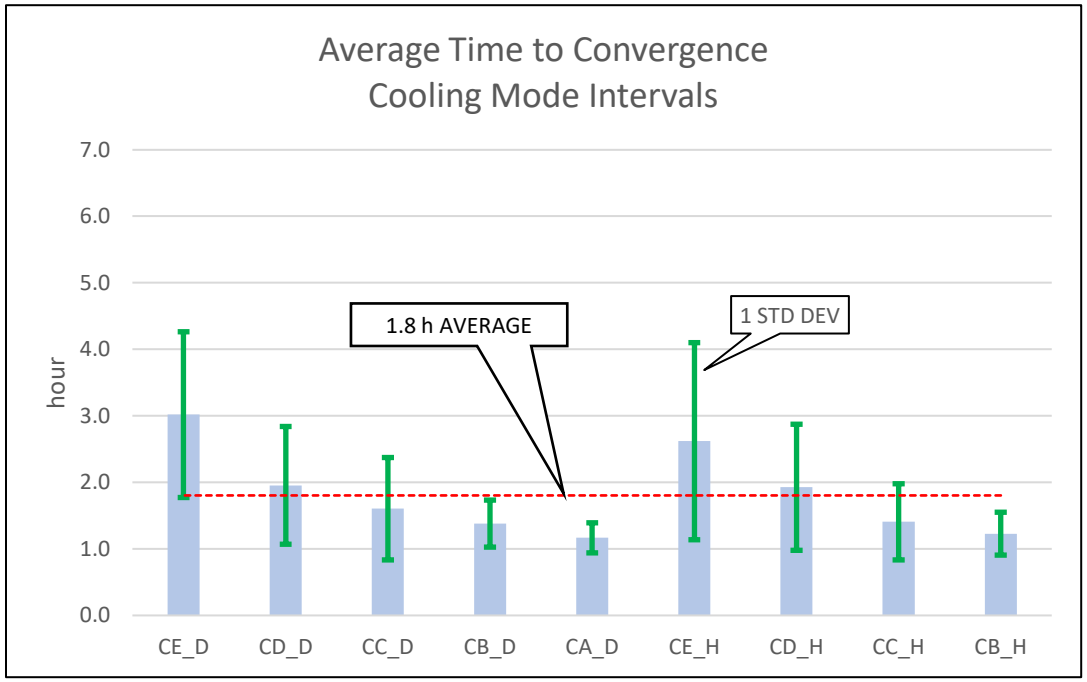


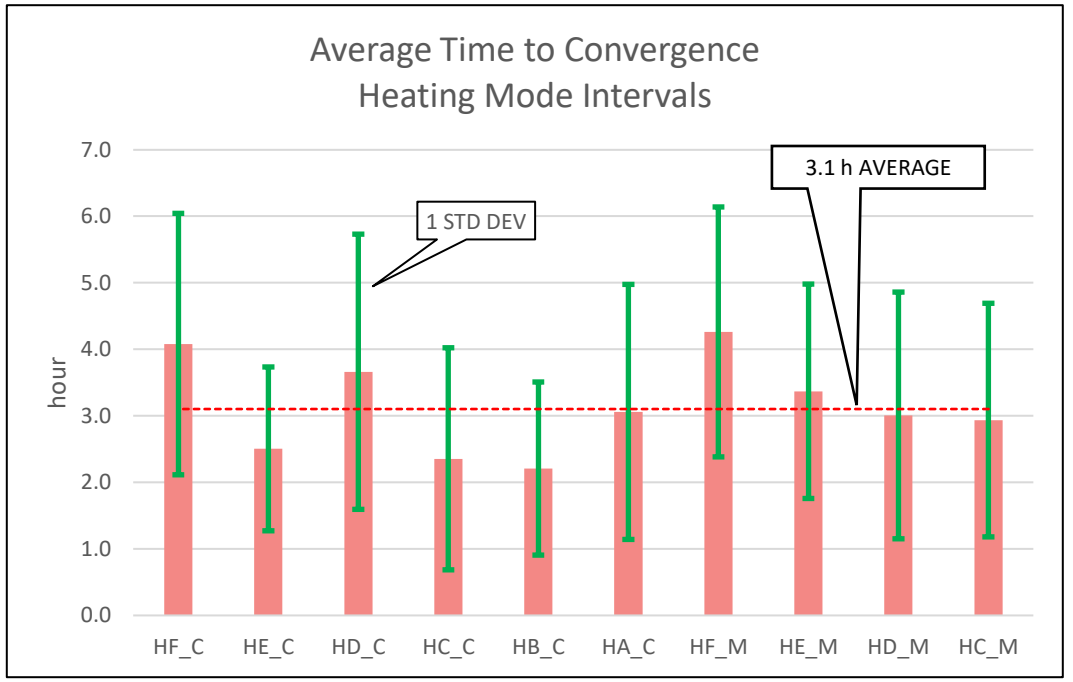
- The average cooling mode test interval time is 1.8 h
- A solid relationship between building load and test times can be seen
- Standard deviations decrease with increasing building loads
  - Max and min STD DEV values are 1.5 h and 0.2 h, respectively
  - The standard deviations can be used to reflect variability in the data set, and consistency (or inconsistency) in how test units handle the particular test interval conditions and building load

- The average heating mode test interval time is 3.1 h
- A solid relationship between building load and test times can be seen with the Marine set of intervals; less of a relationship exists with the Continental set of intervals
- Standard deviations are higher than those of the cooling mode intervals and are scattered throughout the heating mode intervals
  - Max and min STD DEV values are 2.1 h and 1.2 h, respectively

EXP07 Value Engineering

1. Baselines: Test Interval Times – Time to Convergence





Overall:

- Test interval times for cooling mode are shorter than those of the heating mode; cooling mode intervals are easier to run
- For cooling mode, the test interval times decrease with load; units seem to have operating challenges with lower loads
- For heating mode, in general the test interval times decrease with load and units seem to have operating challenges with lower loads. The defrost operation that occurs with heat pumps when operating in the heating mode is a known contributor to challenges associated with running heating mode intervals, and the associated increased test interval times as compared to the cooling mode intervals

EXP07 Value Engineering

CONTENTS:

1. Develop baselines for:
   A. Test Interval Times (Time to Convergence)
   B. Convergence (how often does it NOT occur? why doesn't it occur?)
   C. Test Burden: AHRI vs EXP07
2. Streamlining Opportunities
   A. Reduce Test Interval Times
      I. Reduce convergence periods from 20 min to 15 min
      II. Reduce 4h (cooling) and 6h (heating) max interval requirements

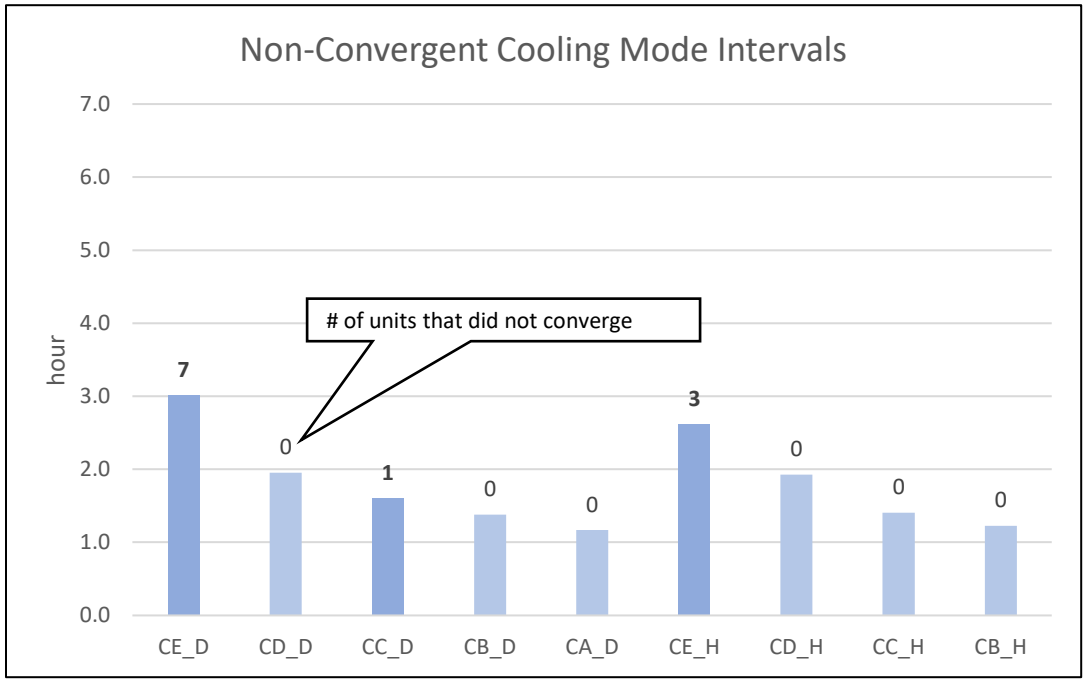
EXP07 Value Engineering

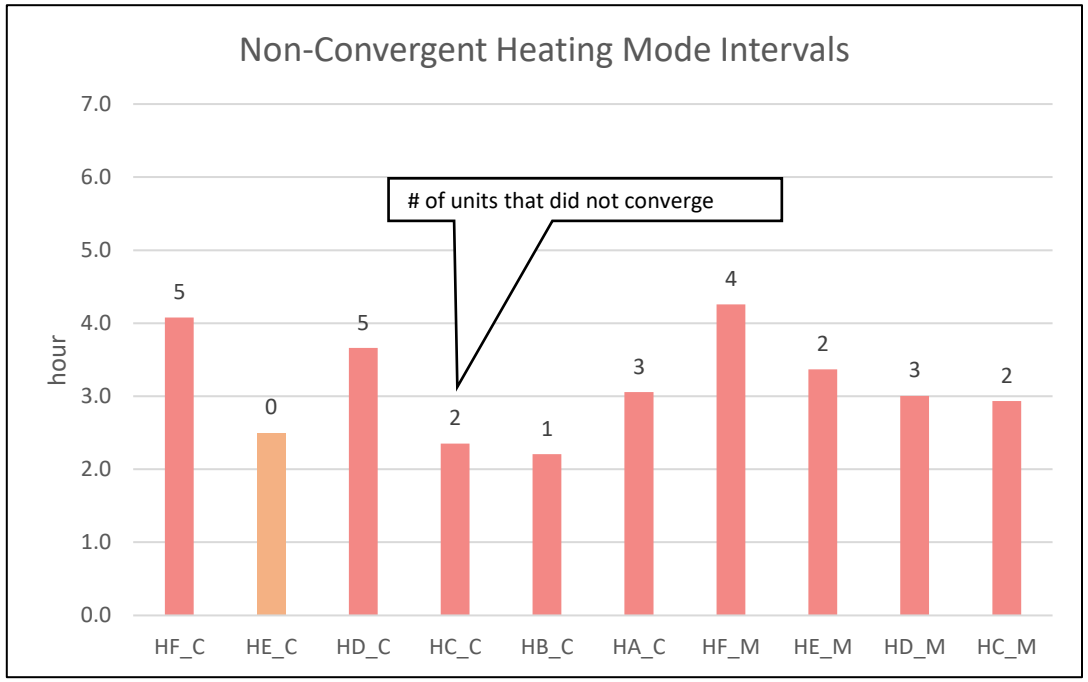
1. Baselines: Convergence - How often does it NOT occur and why?

- A sample of 15 variable-speed heat pumps that have been tested to the full compliment of EXP07 test intervals were used for this baseline determination
- 12 ductless units, 3 ducted units
- Convergence occurs during each test interval when the COP values for two separate and consecutive 20-minute (minimum) periods of time are within 1% of the average COP of the two separate periods
  - Convergence is an indicator of stability of measured data; when convergence occurs, the data contained within the overall convergence period is of a certain stability
  - As seen in the previous Test Interval charts, it takes anywhere from 1 h - 4 h (cooling) or 1 h - 6 h (heating) for convergence to occur
  - If convergence does not occur within 4 h of running a cooling interval or 6 h of running a heating interval, the COP for the interval is based on the entire 4 h or 6 h of data collected within those time frames
- Of the 15 units sampled:
  - 2 units converged on all 19 cooling and heating test intervals
  - Of the 13 units that had non-converging intervals, the range of non-convergent intervals was 1-6
  - The average # of non-convergent intervals of the group of 15 units was 2.5
- The charts in the next 5 slides provide summaries of the number of units for which convergence did not occur during the execution of each test interval, and a matrix of contributing reasons for the non-convergence for each of the intervals

EXP07 Value Engineering

1. Baselines: Convergence - How often does it NOT occur and why?

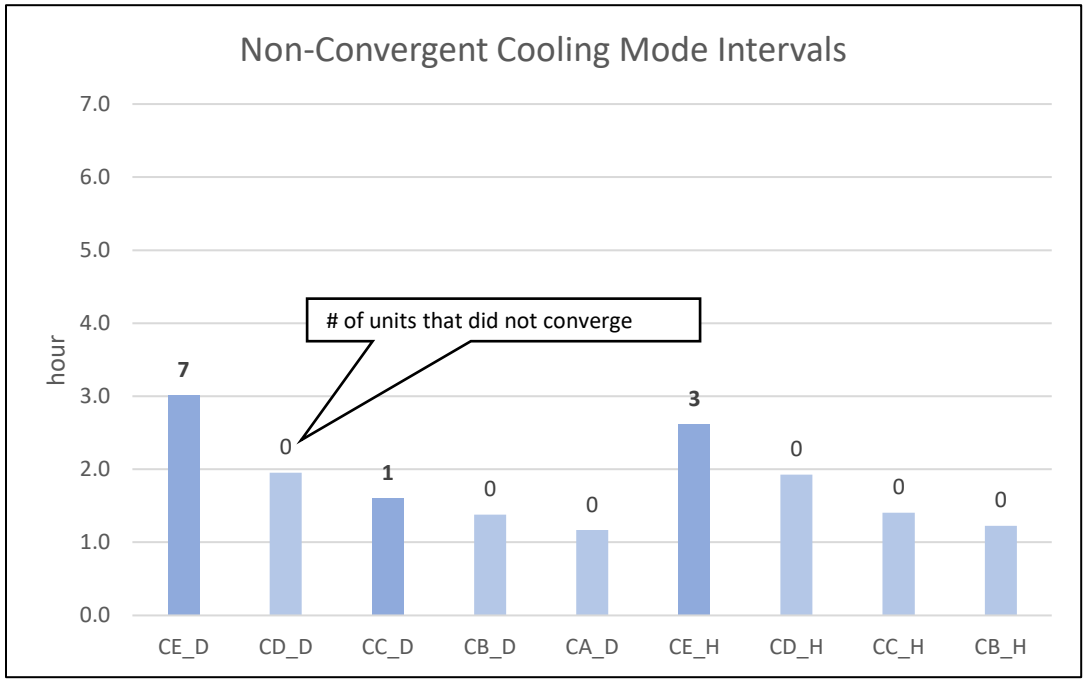




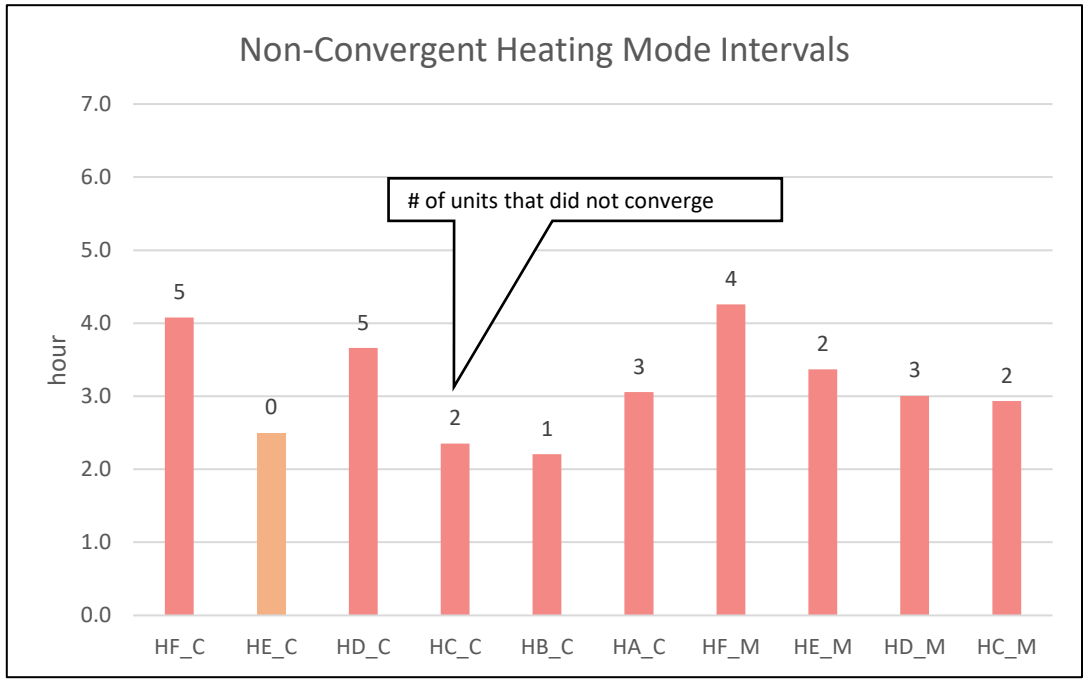
- Individual test intervals are along the horizontal axes; units of hours are along the vertical axes
- Two sets of test intervals are seen for cooling (Dry and Humid) and heating (Continental and Marine)
- Increasing building loads are displayed from left to right; lowest load on the left, highest load on the right (of each set)
- The number of units (of the 15 in the sample) that did not converge for each test interval is displayed above the vertical (time) bars

EXP07 Value Engineering

1. Baselines: Convergence - How often does it NOT occur and why?



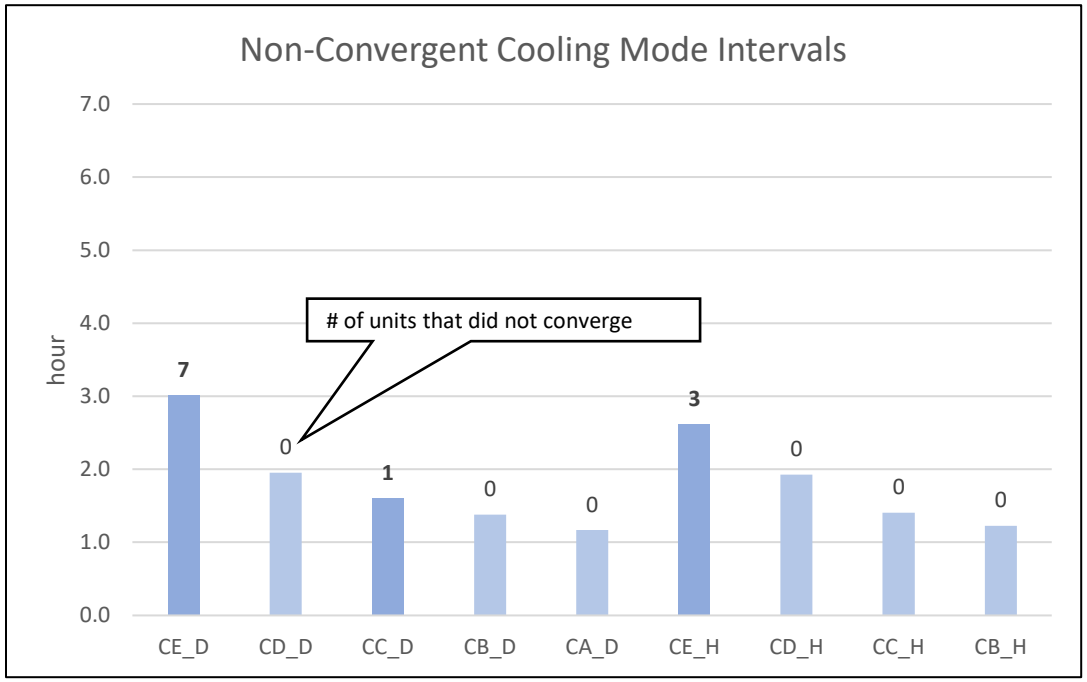
- A fairly solid relationship can be seen between building load and number of non-convergent units
- The lowest load cooling intervals for the Dry and Humid groups, CE_D and CE_H, respectively, have the highest number of non-convergent units
  - These intervals also had the highest degree of variation (standard deviation) in their average test times
- All 15 of the sampled units were able to converge during 6 of the 9 cooling mode intervals

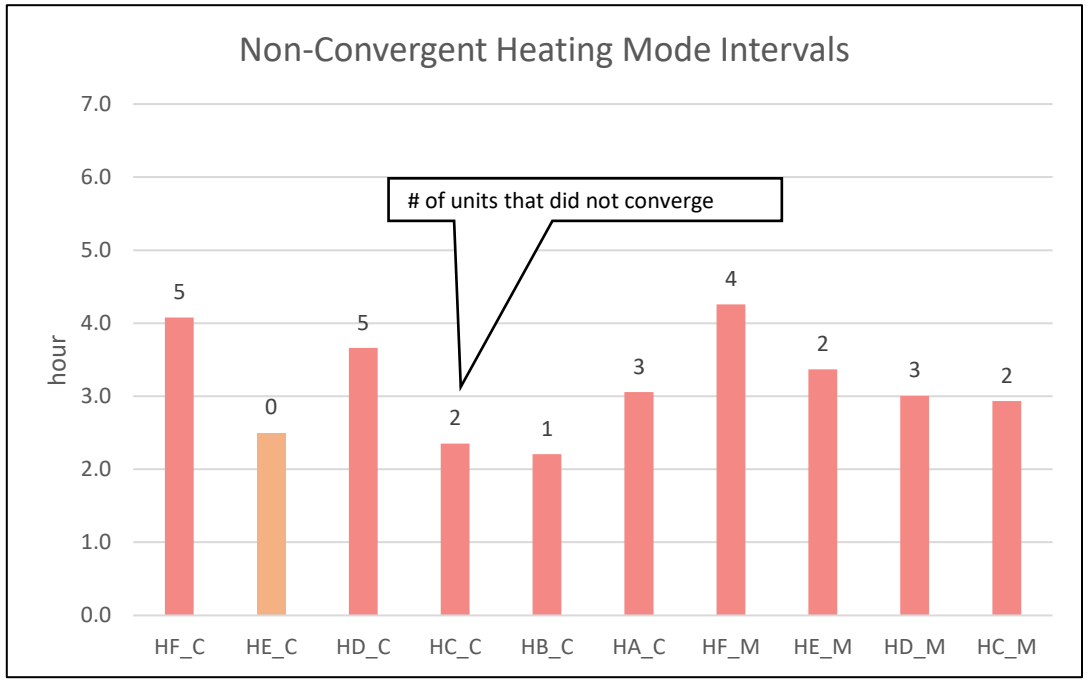


- A fairly solid relationship between building load and number of non-convergent units can be seen with the Marine set of intervals; less of a relationship exists with the Continental set of intervals
- The lowest load heating interval for the Continental group (HF_C) shares the highest number of non-convergent units in that group with the HD_C interval. The lowest load heating interval for the Marine group (HF_M) has the highest number of non-convergent units in that group
  - These intervals also had the highest degree of variation (standard deviation) in their average test times
- There was only one test interval (HE_C) during which all 15 of the sampled units were able to converge.

EXP07 Value Engineering

1. Baselines: Convergence - How often does it NOT occur and why?



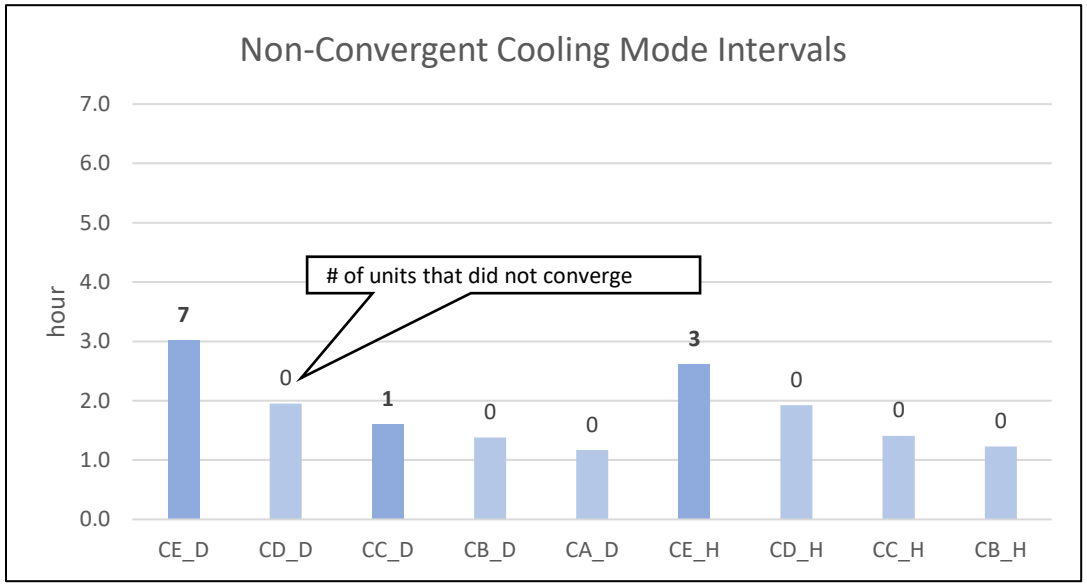


Overall:

- Cooling mode intervals have fewer non-converging test intervals than those of the heating mode; cooling mode intervals are easier to run
- For cooling mode, the number of non-convergent units decreases with load; units seem to have operating challenges with lower loads
- For heating mode, in general the number of non-convergent units decreases with load and units seem to have operating challenges with lower loads. The defrost operation that occurs with heat pumps when operating in the heating mode is a known contributor to challenges associated with running heating mode intervals, and the associated higher number of units that do not converge during heating mode test intervals, as compared to the cooling mode intervals

EXP07 Value Engineering

1. Baselines: Convergence - How often does it NOT occur and why? COOLING MODE CONTRIBUTORS

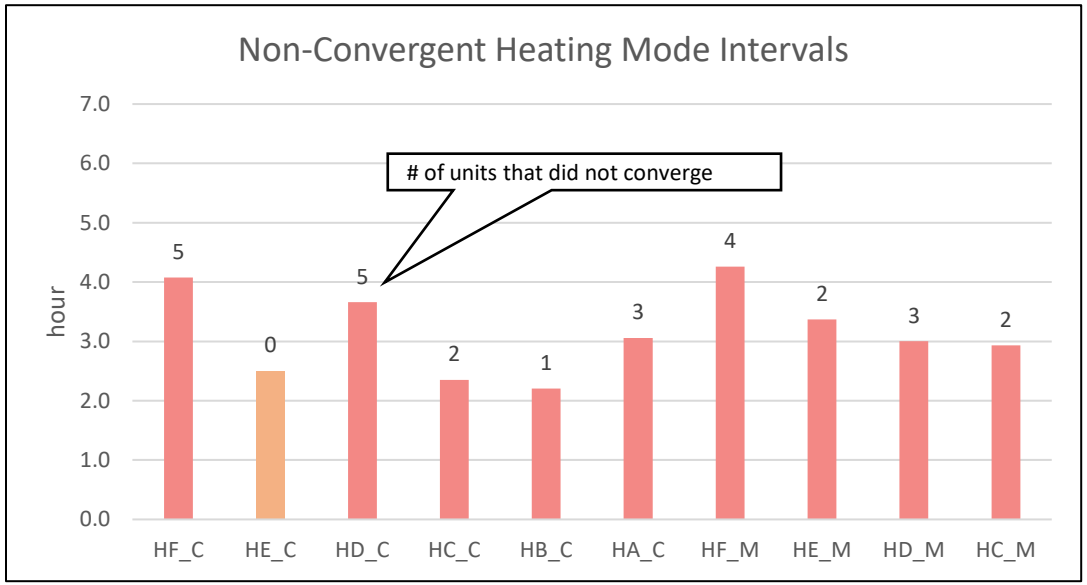


	Irregular ON/OFF Cycling	Other Operating Modes
CE_D 7 units	✓	
	✓	
	✓	
	✓	
	✓	
	✓	
	✓	
CC_D 1 unit	✓	
CE_H 3 units	✓	
	✓	
	✓	

- In every situation, irregular ON/OFF cycling of the UUT contributed to the in-stability of the test interval and the non-convergence

EXP07 Value Engineering

1. Baselines: Convergence - How often does it NOT occur and why? HEATING MODE CONTRIBUTORS



	Irregular ON/OFF Cycling	Defrost Operation
HF_C 5 units	✓	
	✓	
	✓	
	✓	
	✓	
HD_C 5 units	✓	✓
	✓	✓
		✓
	✓	✓
	✓	✓
HC_C 2 units		✓
		✓
HB_C 1 unit		✓
HA_C 3 units		✓
		✓
		✓
HF_M 4 units	✓	
	✓	
	✓	
	✓	
HE_M 2 units	✓	✓
	✓	
HD_M 3 units	✓	✓
		✓
	✓	✓
HC_M 2 units		✓
		✓

- As the building load increases, the main contributor to the non-convergence transitions from irregular ON/OFF cycling to a combination of irregular ON/OFF cycling & defrost operation to defrost operation. This pattern occurs in both sets of test intervals (marine and continental).

EXP07 Value Engineering

CONTENTS:

1. Develop baselines for:
   A. Test Interval Times (Time to Convergence)
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   C. Test Burden: AHRI vs EXP07
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   A. Reduce Test Interval Times
      I. Reduce convergence periods from 20 min to 15 min
      II. Reduce 4h (cooling) and 6h (heating) max interval requirements

EXP07 Value Engineering

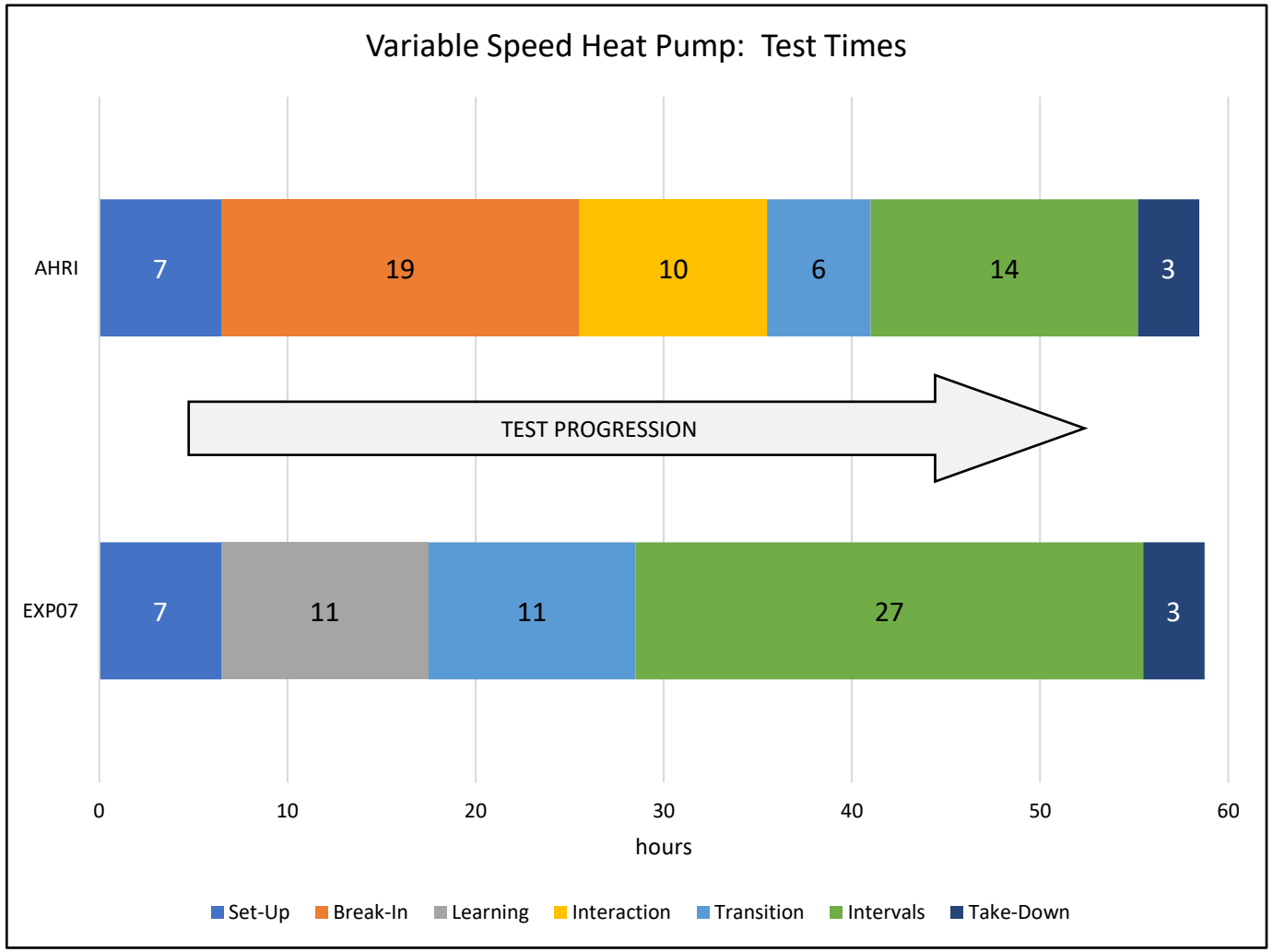
1. Baselines: Test Burden – AHRI vs EXP07

- How much lab time does it take to complete a test sequence for the purpose of determining energy efficiency metrics for single cooling and heating climate zones?
  - AHRI: SEER2 and HSPF2
  - EXP07: $SCOP_C$ and $SCOP_H$

- Test Sequence Process Steps
  - **Set-Up**: Installing the UUT for testing in the laboratory psychrometric chambers
  - **Break-In:** Running of the UUT prior to conducting the test intervals for the purpose of optimizing its performance
  - **Learning:** Progression of intervals that allow for UUT to 'learn' its environment and optimize its performance
  - **Interaction:** Manual setting and adjusting of UUT compressor speed and ID blower fan speed based on test interval requirements
  - **Transition:** Adjusting of chamber room test conditions prior to running the first test interval and upon completion of each test interval
  - **Intervals:** Data collection periods for each of the test intervals
  - **Take-Down:** Removing the UUT from the laboratory upon completion of testing

EXP07 Value Engineering

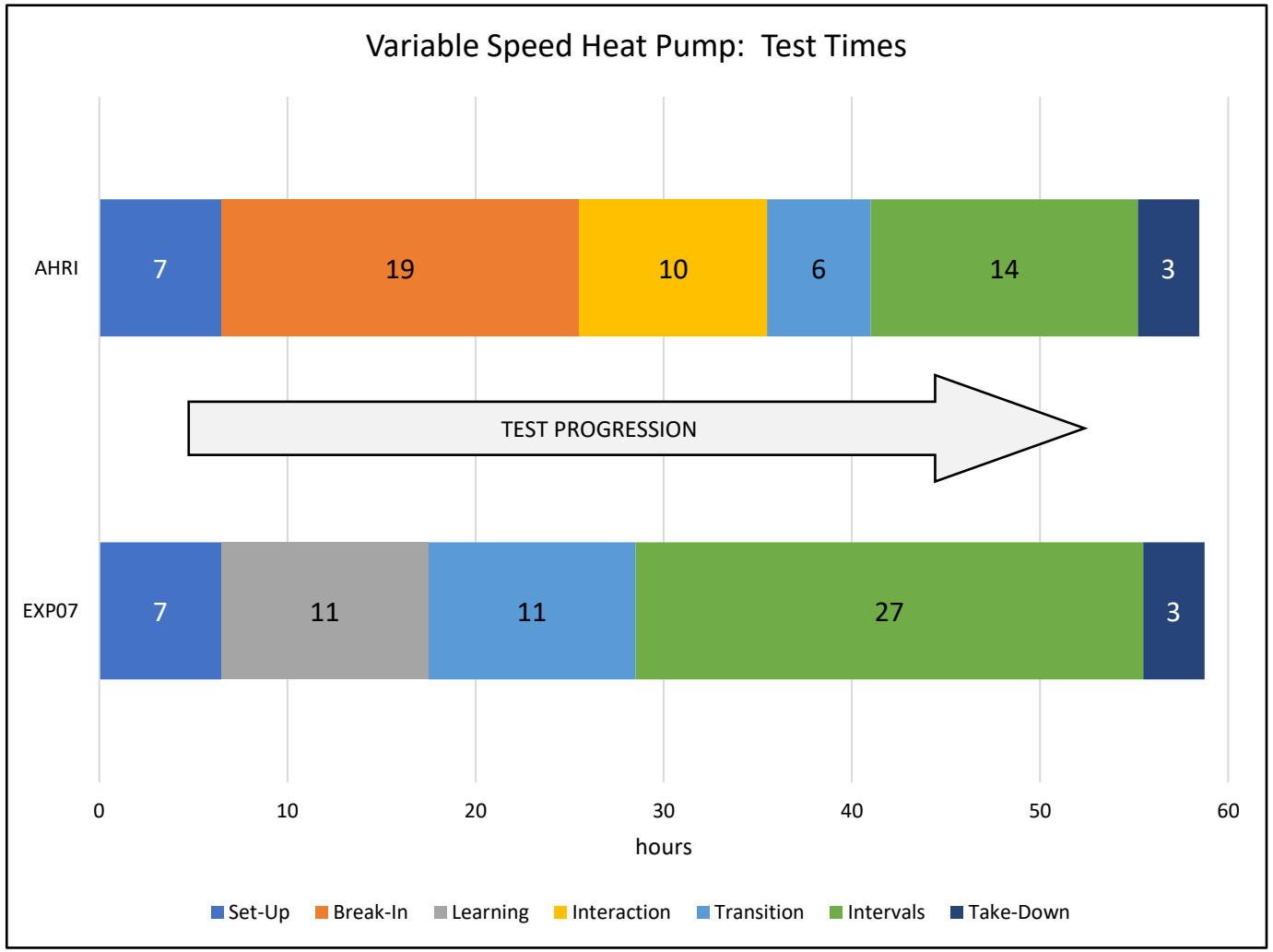
1. Baselines: Test Burden – AHRI vs EXP07



- **Set-Up**: Similar times between AHRI and EXP07. Both procedures follow ASHRAE 37 requirements.
- **Break-In**: Manufacturer-specified for AHRI. Most require 16–20-hour break-in periods. Not required for EXP07
- **Learning**: Required cycles (cooling Dry and Heating Continental) for EXP07. Not required for AHRI.
- **Interaction**: Required technician interaction with the UUT to set compressor and fan speeds. No interaction between the UUT and the technician is required for EXP07.
- **Transition**: Getting the psychrometric chambers on conditions prior to the conducting of learning cycles and test intervals. Transition times from one interval to the next are equal between AHRI and EXP07 testing. The total transition times are based on the number of intervals.
- **Intervals**: 5 cooling and 6 heating intervals are conducted for AHRI and EXP07. The total time associated with each method is based on actual averages compiled from test data
- **Take-Down**: Similar times between AHRI and EXP07

EXP07 Value Engineering

1. Baselines: Test Burden – AHRI vs EXP07



Test Method	Total Hours	Total Shifts
AHRI	58.5	9.0
EXP07	58.7	9.0

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CONTENTS:

1. Develop baselines for:
   A. Test Interval Times (Time to Convergence)
   B. Convergence (how often does it NOT occur? why doesn't it occur?)
   C. Test Burden: AHRI vs EXP07
2. Streamlining Opportunities
   A. Reduce Test Interval Times
      I. Reduce convergence periods from 20 min to 15 min
      II. Reduce 4h (cooling) and 6h (heating) max interval requirements

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2. Streamlining Opportunities – Reduce Test Interval Times

- Reduce Convergence Time Periods from 20 min to 15 min
  - Examined a sample of 3 units; one at the upper end, one at the middle and one at the lower end of range of total test times from the initial 15 units sampled
  - With the 3 sampled units, examined all dry test intervals related to heating and cooling modes

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2. Streamlining Opportunities – Reduce Test Interval Times

- Reduce Convergence Time Periods from 20 min to 15 min: RESULTS

UUT	Mode	Conv Period	COP_{AVG}	Time to Conv (h)
NEEA4_1 ductless	Cooling	20 min	4.09	8.9
		15 min	4.08	8.2
NEEA7_1 ducted	Cooling	20 min	3.37	9.4
		15 min	3.29	8.6
NRCan7 ductless	Cooling	20 min	3.07	12.7
		15 min	3.07	12.5

UUT	Mode	Conv Period	COP_{AVG}	Time to Conv (h)
NEEA4_1 ductless	Heating	20 min	3.14	10.1
		15 min	3.18	8.2
NEEA7_1 ducted	Heating	20 min	2.42	15.9
		15 min	2.45	15.1
NRCan7 ductless	Heating	20 min	2.25	19.7
		15 min	2.25	19.5

- Notes
  - Cooling intervals: CE_D, CD_D, CC_D, CB_D, CA; Heating intervals: HF_C, HE_C, HD_C, HC_C, HB_C, HA_C
  - COP_{AVG} = the average of the COP values determined for each of the cooling and heating intervals (essentially, a non-bin-weighted SCOP)
  - Time to Conv = the cumulative time to convergence of each of the cooling and heating intervals

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- Summary
  - Average time to convergence among the 3 sampled units, at 20 min conv time periods = 25.6 h
  - Average time to convergence among the 3 sampled units, at 15 min conv time period = 24.1 h
  - Reduction in time-to-convergence = 5.8% from current 20 min convergence periods
  - COP_{AVG} for Cooling mode dropped by an average of 0.7% using 15 min convergence periods
  - COP_{AVG} for Heating mode increased by an average of 0.9% using 15 min convergence period

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2. Streamlining Opportunities – Reduce Test Interval Times

- Reduce 4h (cooling) and 6h (heating) max interval requirements for times when convergence does not occur
  - As seen on previous slides, non-convergence occurs more often with heating mode test intervals than with cooling mode test intervals
  - In heating mode, the UUT operating mode associated with non-converging test intervals transitions from ON/OFF cycling to defrost as the induced building load increases.
  - Examined all five of the HF_C intervals that did not converge (see slide 16)
    - Determined COP values across all complete ON/OFF cycles within 6 h, 5 h and 4 h periods
    - Screenshots of these five intervals are provided in slides 28-32
  - Examined all five of the HD_C intervals that did not converge (see slide 16)
    - These intervals proved to be more complicated to assess due to the defrost operations that occurred during each of the intervals
    - These intervals, and associated convergence criteria, will be assessed in more detail during the EXP07 revision process
    - Screenshots of these five intervals are provided in slides 34-38

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2. Streamlining Opportunities – Reduce Test Interval Times

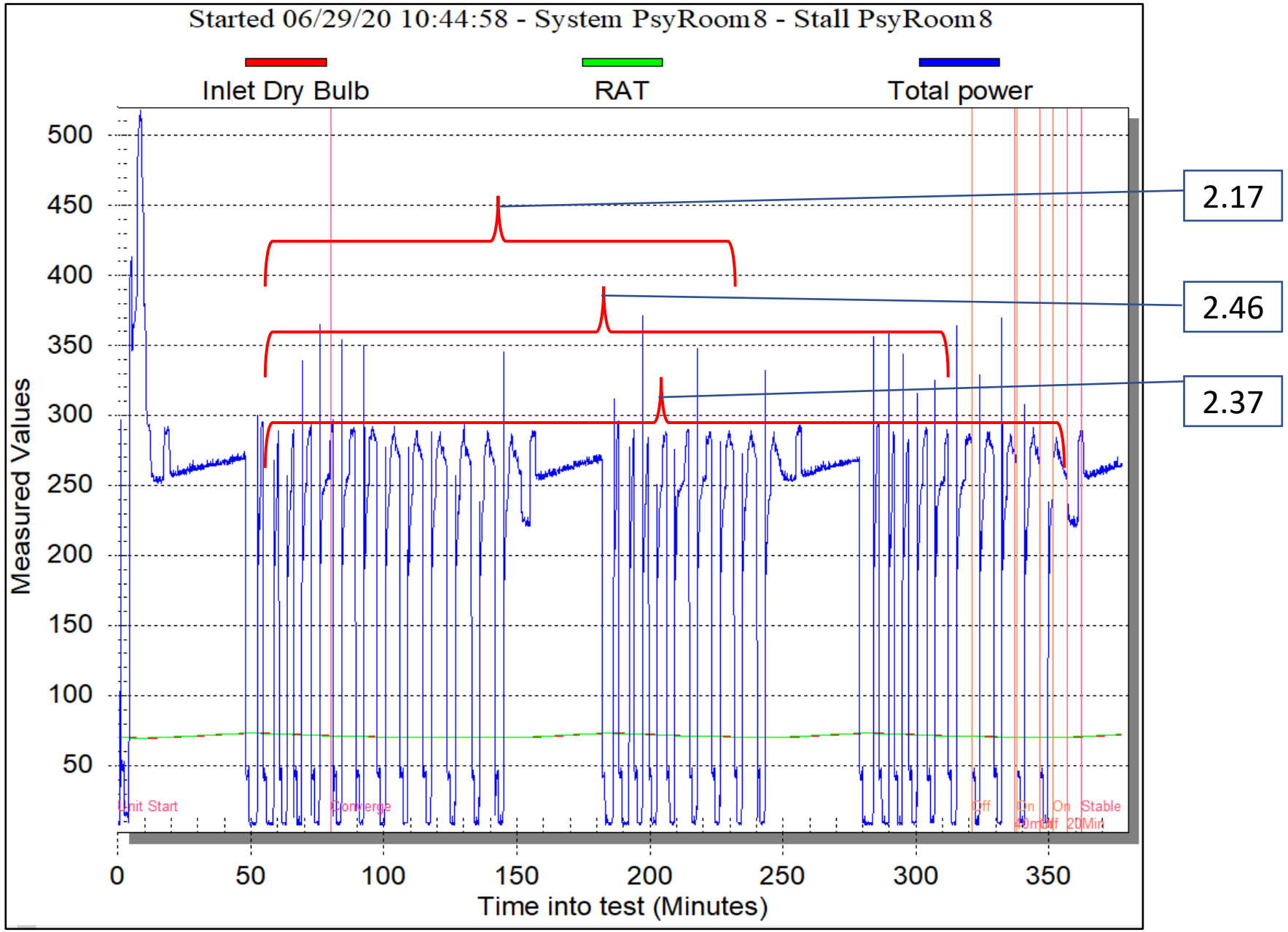
- HF_C intervals that did not converge

	HF_C COP values			% diff from 6 h		
	6 h	5 h	4 h	5 h	4 h	
NEEA4_1	2.37	2.46	2.17	-3.8%	8.4%	OO & VS operating modes (OO=inefficient; VS=efficient)
NRCan7	2.58	2.55	2.61	1.2%	-1.2%	OOH operating mode (spikes)
NEEA9	2.56	2.59	2.72	-1.2%	-6.3%	OO & VS operating modes
NRCan2	2.91	2.88	2.89	1.0%	0.7%	OO operating mode (a bit irregular)
NEEA2	3.51	3.49	3.49	0.6%	0.6%	OO operating mode (a bit irregular)

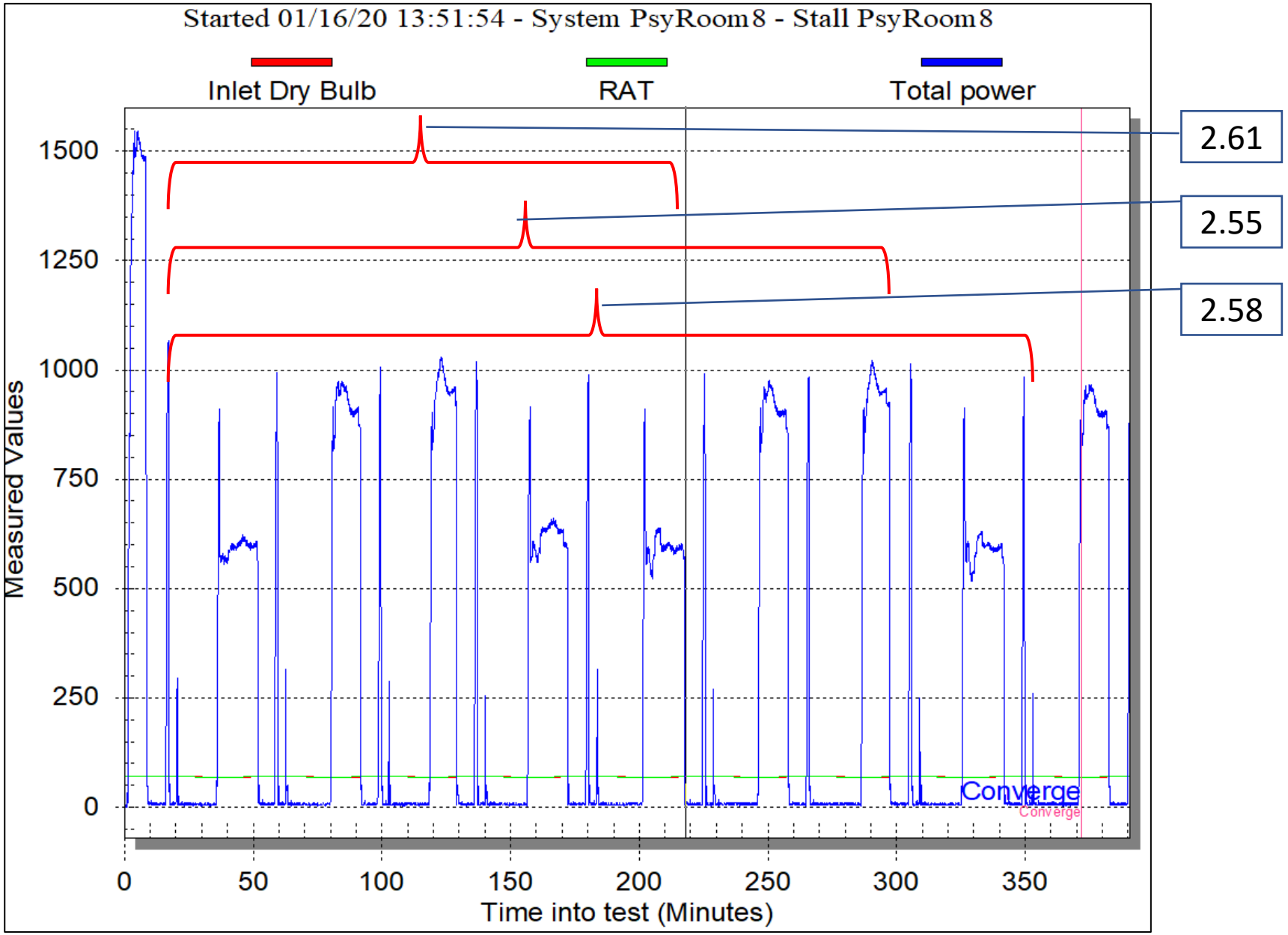
these look promising

- The determination of COP for test intervals where the UUT exhibits multiple operating modes across the entire 6 h period is challenging
- The following 5 slides show screenshots of the HF_C intervals that were assessed for each of the 5 units

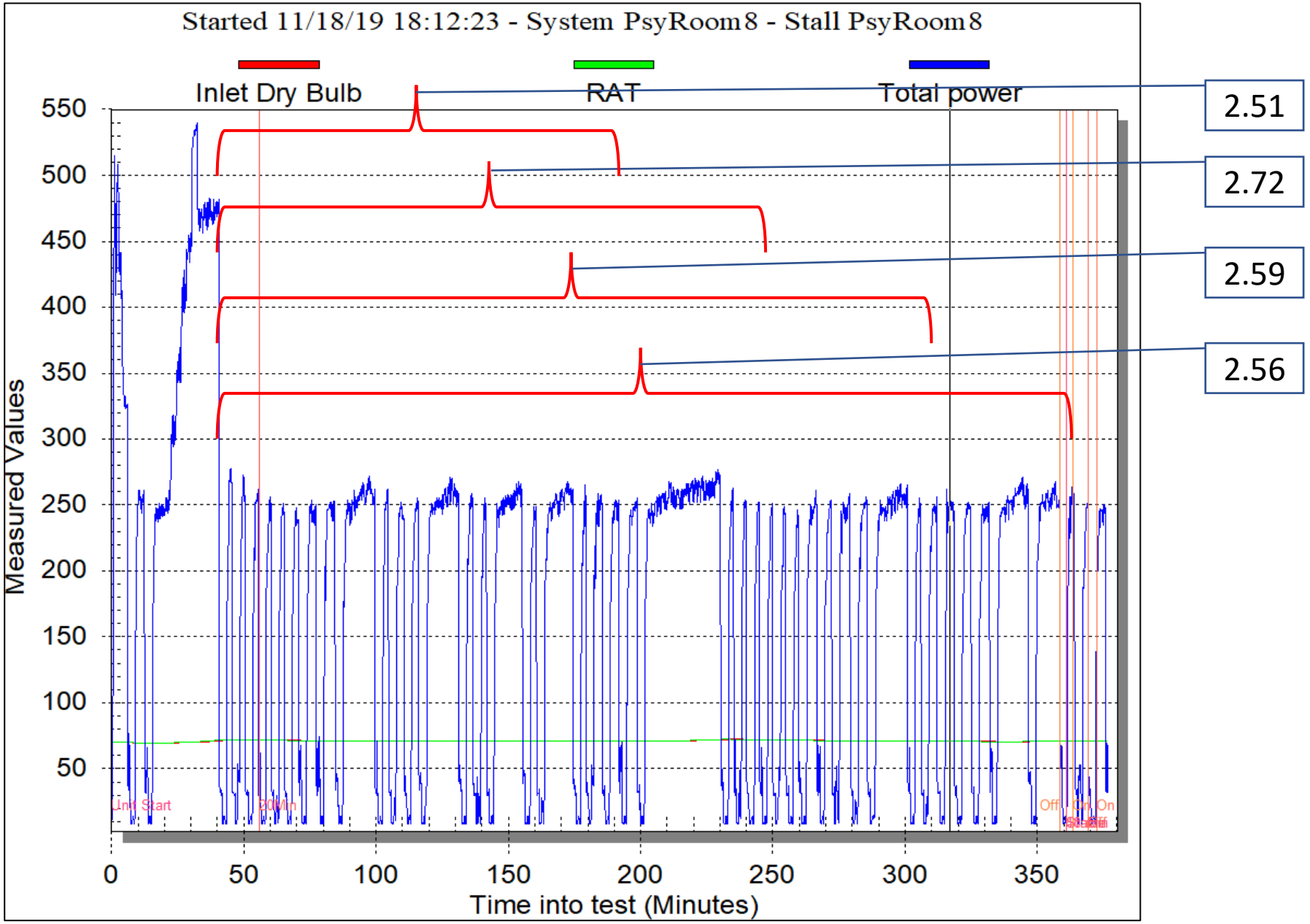
NEEA4_1 HF_C


Started 06/29/20 10:44:58 - System PsyRoom8 - Stall PsyRoom8
Inlet Dry Bulb
RAT
Total power
Measured Values
500
450
400
350
300
250
200
150
100
50
0
50
100
150
200
250
300
350
Time into test (Minutes)
Unit Start
Converge
Off
On
Stable
2.17
2.46
2.37

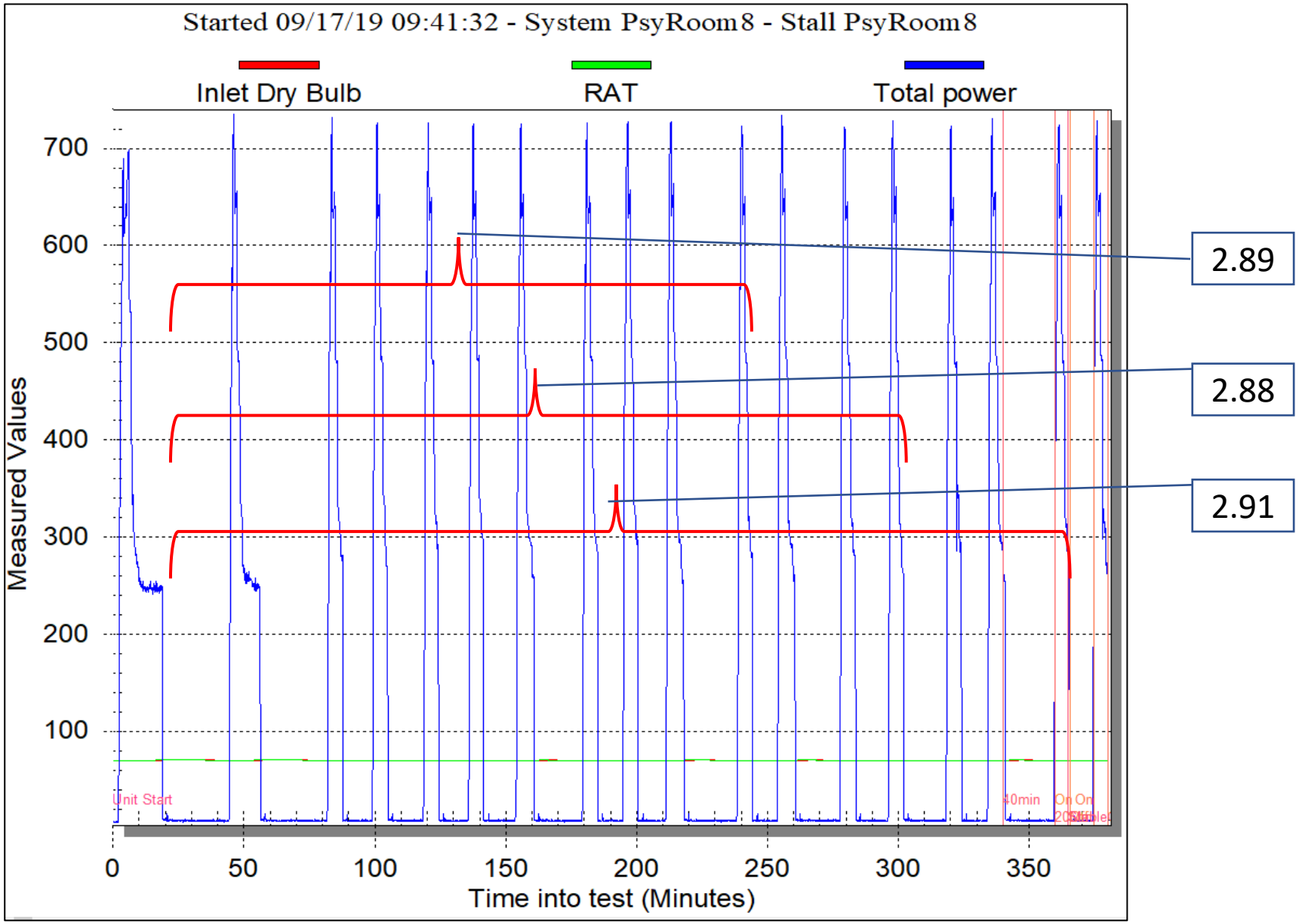
NRCan7 HF_C


Started 01/16/20 13:51:54 - System PsyRoom8 - Stall PsyRoom8
Inlet Dry Bulb
RAT
Total power
Measured Values
1500
1250
1000
750
500
250
0
0
50
100
150
200
250
300
350
Time into test (Minutes)
Converge
2.61
2.55
2.58

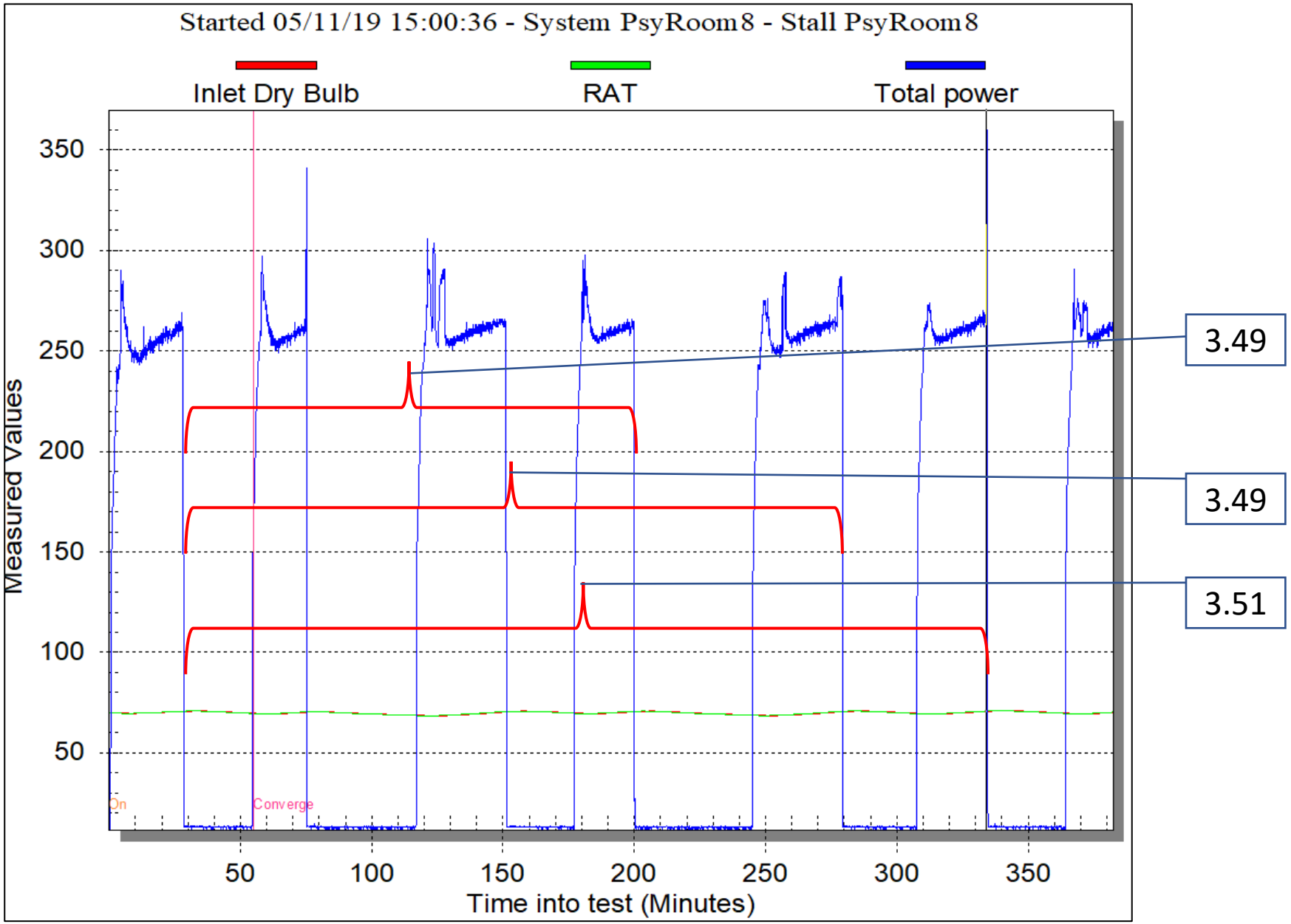
NEEA9 HF_C


Started 11/18/19 18:12:23 - System PsyRoom8 - Stall PsyRoom8
Inlet Dry Bulb
RAT
Total power
Measured Values
550
500
450
400
350
300
250
200
150
100
50
0
50
100
150
200
250
300
350
Time into test (Minutes)
2.51
2.72
2.59
2.56

NRCan2 HF_C


Started 09/17/19 09:41:32 - System PsyRoom8 - Stall PsyRoom8
Inlet Dry Bulb
RAT
Total power
Measured Values
700
600
500
400
300
200
100
0
50
100
150
200
250
300
350
Time into test (Minutes)
Unit Start
40min
2.89
2.88
2.91

NEEA2 HF_C


Started 05/11/19 15:00:36 - System PsyRoom8 - Stall PsyRoom8
Inlet Dry Bulb
RAT
Total power
Measured Values
350
300
250
200
150
100
50
On
Converge
50
100
150
200
250
300
350
Time into test (Minutes)
3.49
3.49
3.51

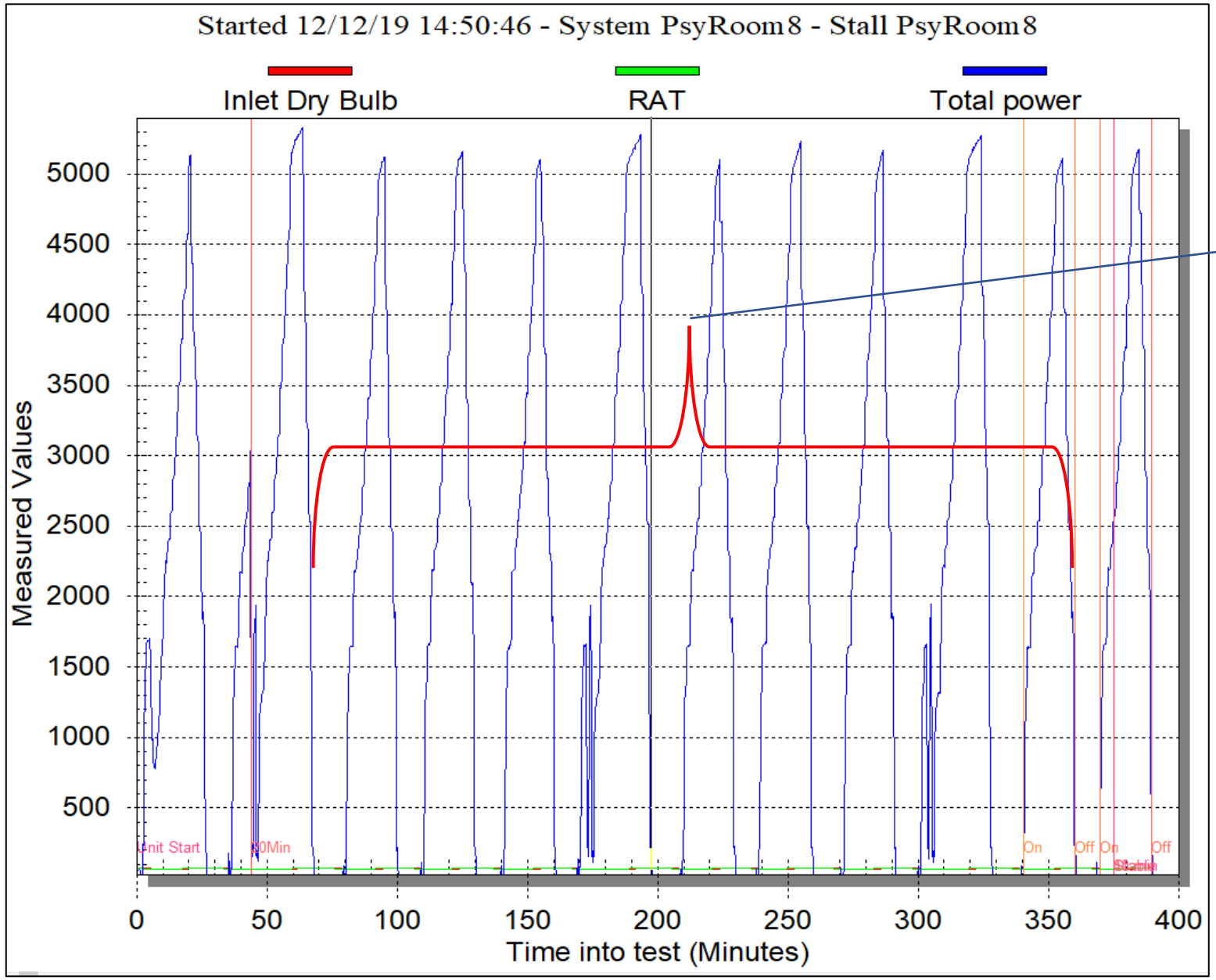
EXP07 Value Engineering

2. Streamlining Opportunities – Reduce Test Interval Times

- HD_C intervals that did not converge

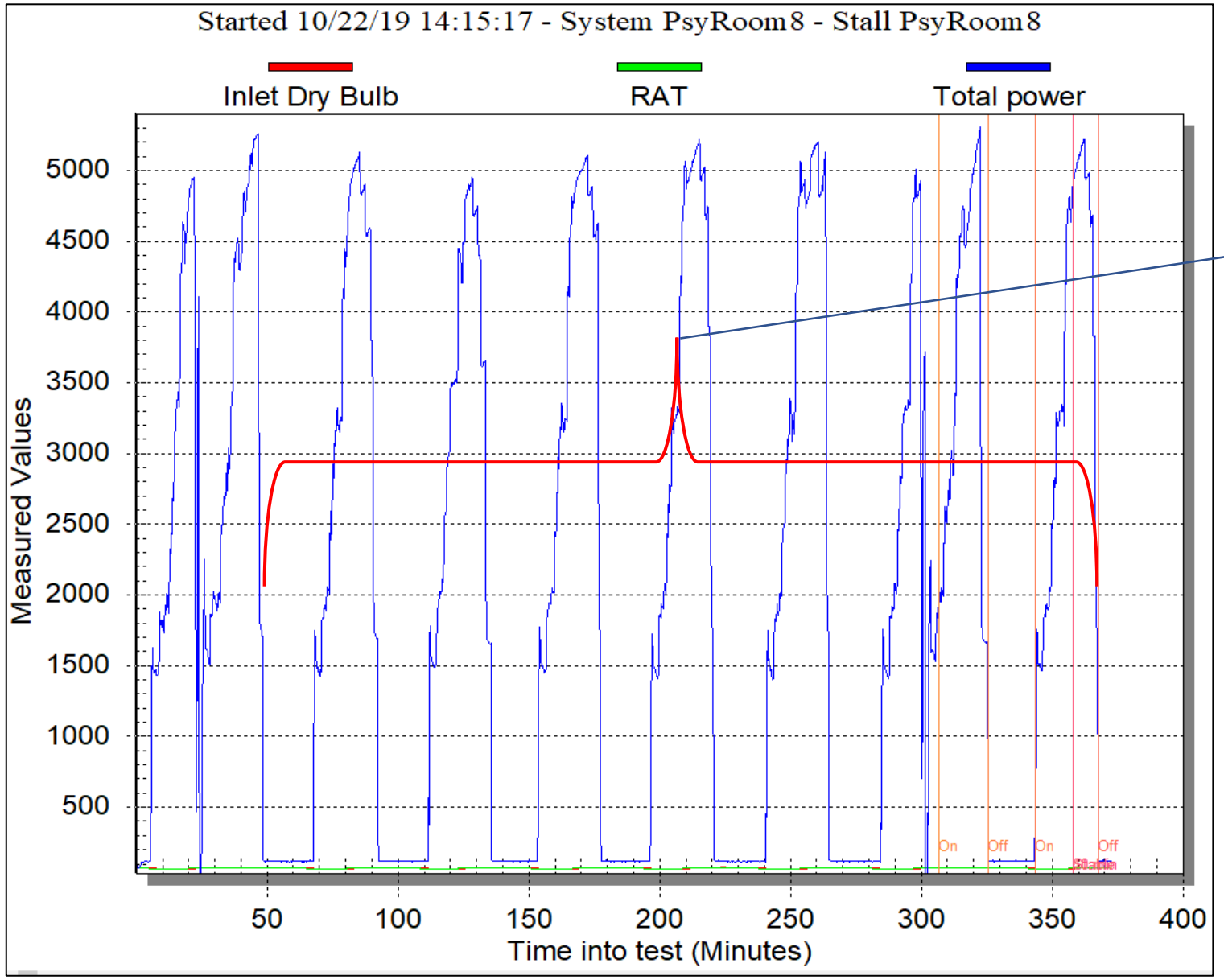
  - These intervals proved to be more complicated to assess due to the defrost operations that occurred during each of the intervals
  - These intervals, and associated convergence criteria, will be assessed in more detail during the EXP07 revision process
  - The following 5 slides show screenshots of the HD_C intervals that were assessed for each of the 5 units

NEEA8 HD_C



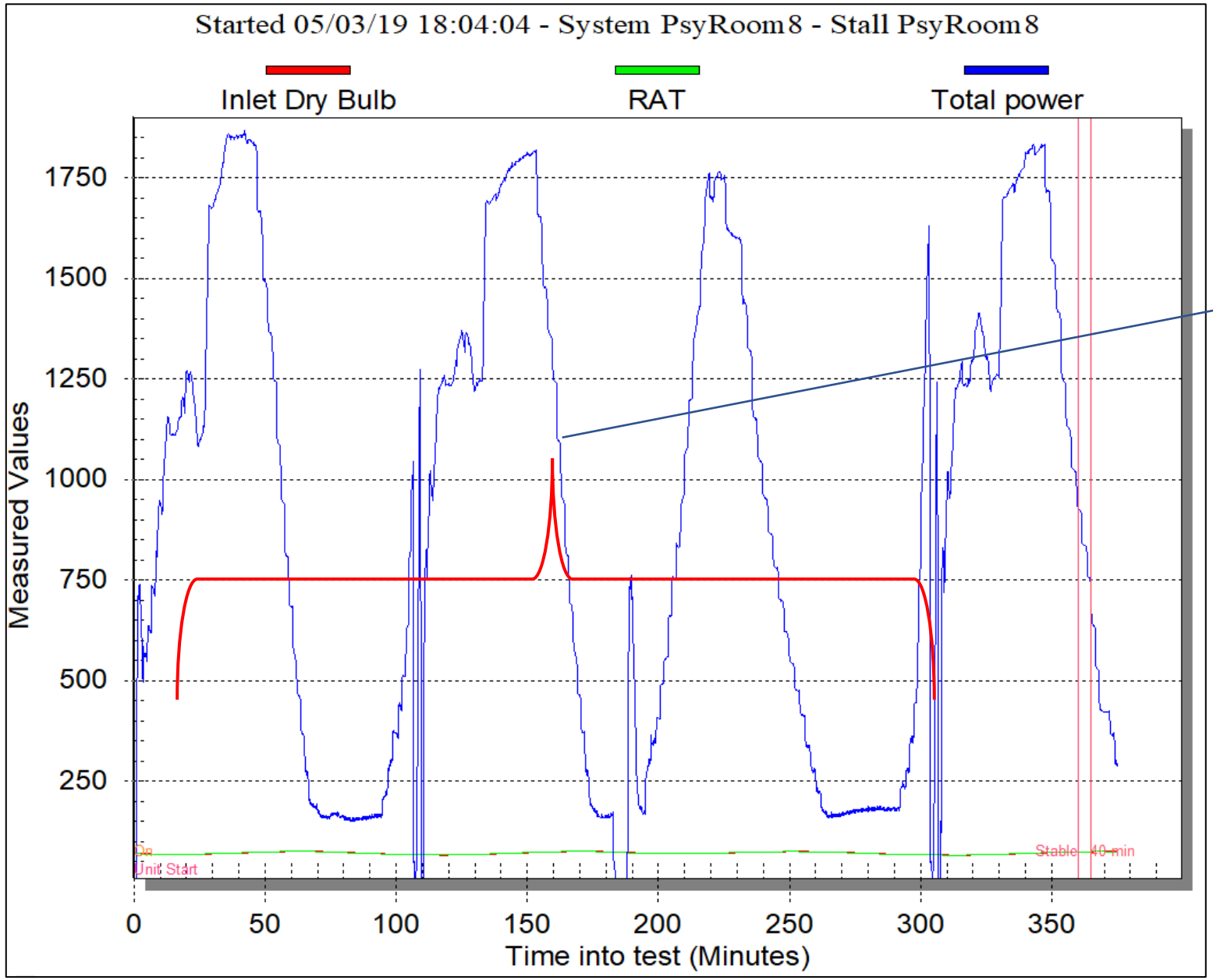
Convergence Period:
Across all complete OO cycles in 6h period

NEEA7_1 HD_C



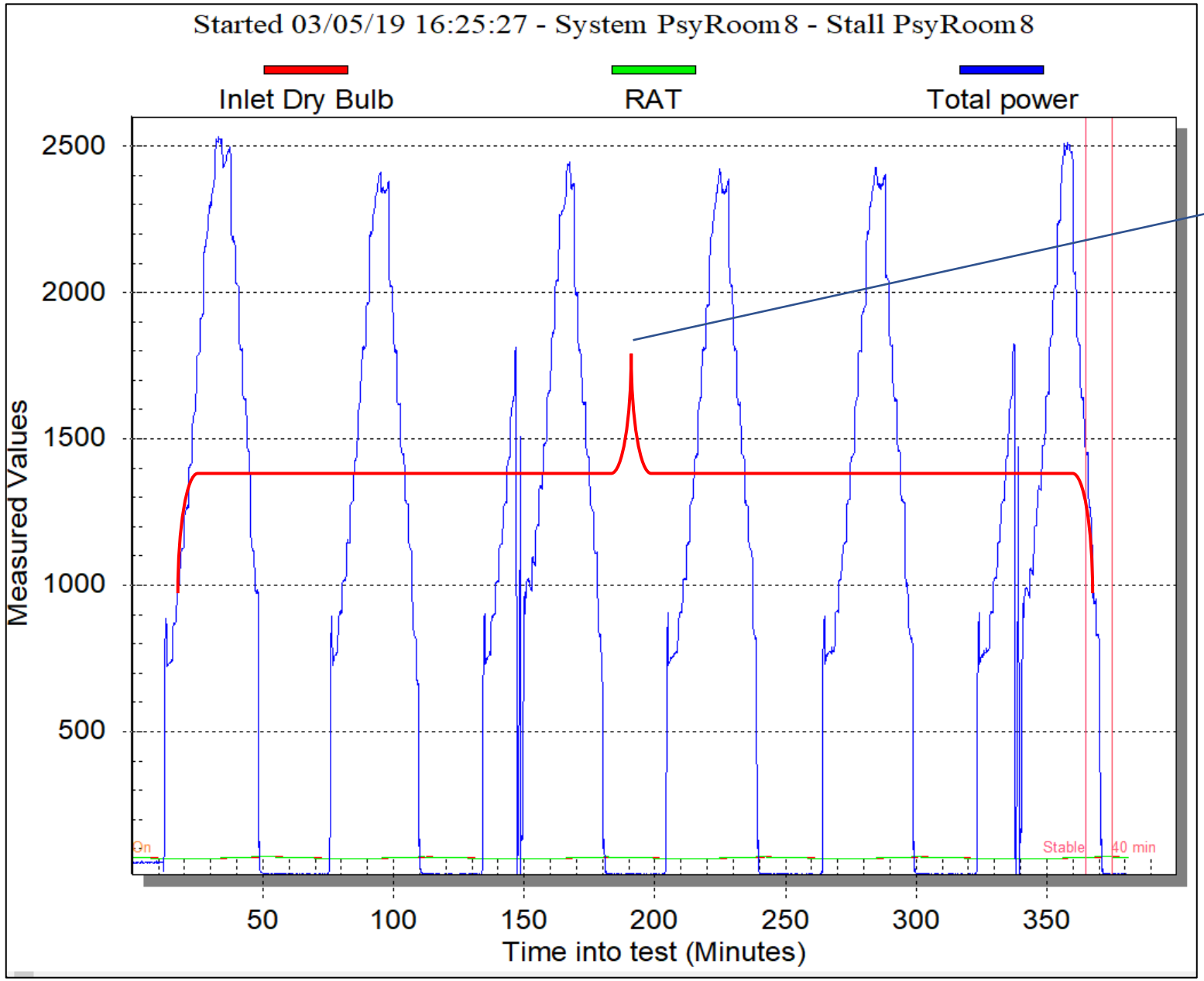
Convergence Period: Across all complete OO cycles in 6 h period

NEEA3 HD_C



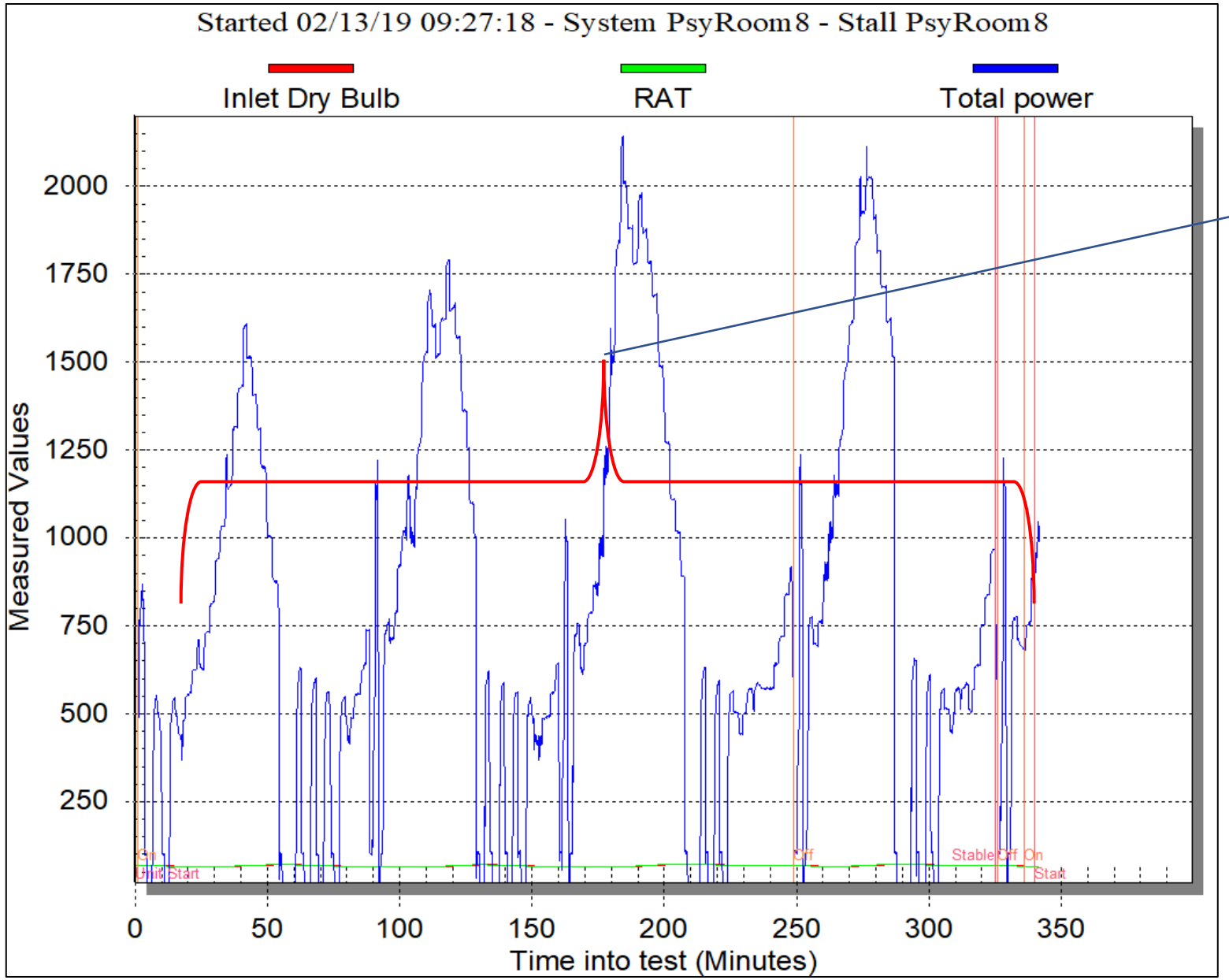
Convergence Period

NRCan5 HD_C



Convergence Period:
Across entire 6 h

NRCan4 HD_C



Convergence Period:
Across entire 5.7 h