Earning HERS Points for Quality HVAC Design & Installation

May 21st, 2019


Introduction

Installation defects in HVAC systems are commonplace

- Improper airflow.
- Incorrect refrigerant charge.

Study Author	State	Existing or New Home?	Sample Size	Average Airflow	Airflow <350 cfm	Airflow w/in 10% of 400/ton	Energy Savings Potential	Notes
Blasnik et al. 1995a	NV							
Blasnik et al. 1995b	CA							
Blasnik et al. 1996	AZ							
Hammarlund et al. 1992	CA							
Hammarlund et al. 1992	CA							
Neme et al. 1997	MD							
Palani et al. 1992	n.a.							
Parker et al. 1997	FL							
Proctor & Pernick 1992	CA							
Proctor 1991	CA							
Proctor et al. 1995a	CA							
Rodriguez et al. 1995	n.a.							
Rodriguez et al. 1995	n.a.							
VEIC/PEG 1997	NJ							
Average								

Study Author	State	Existing or New Homes?	Sample Size	Charge correct to mfg spec	% over charge	% under charge	Energy Savings Potential	Notes
Blasnik et al. 1995a	NV	New	30	35%	5%	59%	17%	Est @ 67% combined charge/air flow correction benefits
Blasnik et al. 1995b	CA	New	10				8%	Est @ 67% combined charge/air flow correction benefits
Blasnik et al. 1996	AZ	New	22	18%	4%	78%	21%	Est @ 67% combined charge/air flow correction benefits
Farzad & O'Neal 1993	n.a.	n.a.	n.a.				5%	Lab test of TXV; 8% loss @20% overchg; 2% loss @20% underchg
Farzad & O'Neal 1993	n.a.	n.a.	n.a.				17%	Lab test of Orifice; 13% loss @20% overchg; 21% loss @ 20% underchg
Hammarlund et al. 1992	CA	New	12				12%	Single family results
Hammarlund et al. 1992	CA	New	66	31%	61%	8%	12%	Multi-family results
Katz 1997	NC/SC	New	22	14%	64%	23%		Charge measured in 22 systems in 13 homes
Proctor & Pernick 1992	CA	Existing	175	44%	33%	23%		Results from PG&E Model Energy Communities Program
Proctor 1991	CA	Existing	15	44%				Fresno homes
Proctor et al. 1995a	CA	Existing	30	11%	33%	56%		
Proctor et al. 1997a	NJ	New	52				13%	Est @ 67% combined charge/air flow correction benefits
Rodriguez et al. 1995	n.a.	n.a.	n.a.				5%	Lab test of TXV EER; 5% loss at both 20% overchg & 20% underchg
Rodriguez et al. 1995	n.a.	n.a.	n.a.				15%	Lab test of Orifice EER; 7% loss @20% overchg, 22% loss @ 20% underchg
Average				28%	33%	41%	12%	

Why is this relevant to HERS / ERI ratings?

- Today, installation faults have zero impact on a HERS or ERI rating.
- Not only do these faults impact efficiency, they impact performance.
- ENERGY STAR has promoted quality installation since 2011.
- However, uniform and practical procedures for Raters to assess systems will be a more effective approach.
- And, HERS / ERI points can be granted in exchange.

A standard is born

- ACCA initiated a proposal that RESNET include an evaluation of HVAC design and installation in the HERS index.
- In Summer 2016, EPA started leading a working group.
- The working group encompasses a diverse set of stakeholders interested in solving this problem:

Jim Bergman, Measure Quick	Laurel Elam, RESNET	Brian Mount, Tempo Air
Tommy Blair, AE	Philip Fairey, FSEC	Dave Roberts, NREL
Michael Brown, ICF	Dean Gamble, EPA	Dennis Stroer, CalcsPlus
Greg Cobb, EI	Dan Granback, EI	Iain Walker, LBNL
Wes Davis, ACCA	James Jackson, Emerson	Dan Wildenhaus, TRC
Brett Dillon, IBS Advisors	Rob Minnick, Minnick's Inc.	Jon Winkler, NREL

Guiding principles of the standard

- Take a 'carrot' rather than a 'stick' approach.
- Reward incremental improvement by HVAC professionals and Raters.
- Rely upon procedures that deliver value in and of themselves.

Conceptual overview of standard

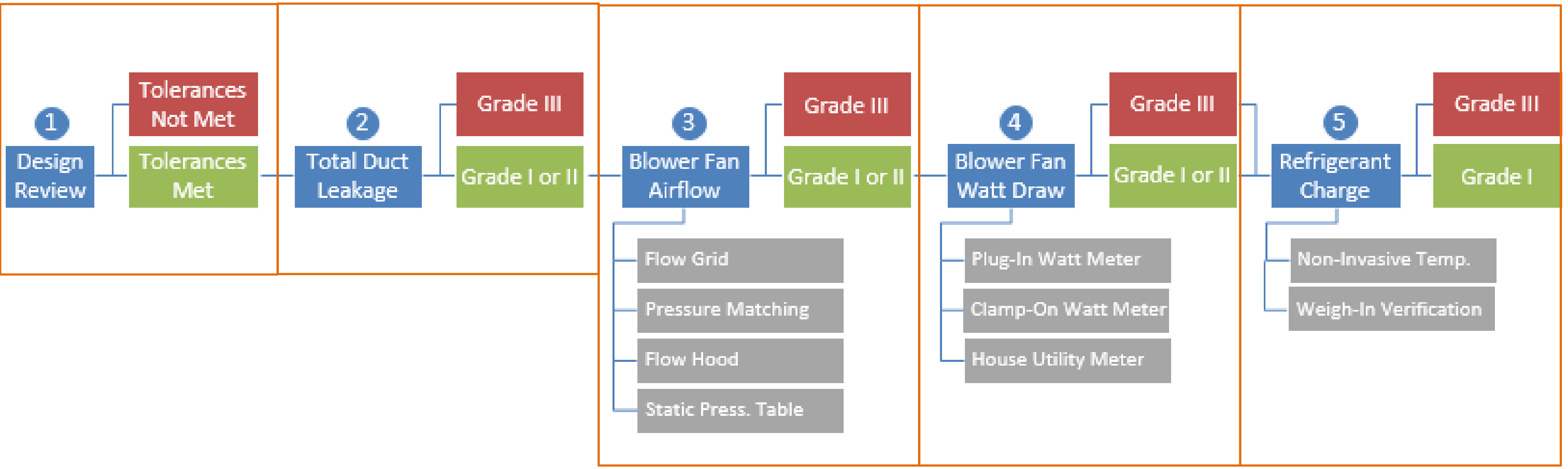
- Follow the insulation quality-installation model:
  - Grade III:
    - The default.
    - HVAC system installation quality is not assessed.
    - No HERS points earned (but no penalty either).
  - Grade II:
    - Rater assesses HVAC system.
    - HVAC system installation quality is so-so.
    - Some HERS points are earned.
  - Grade I:
    - Rater assesses HVAC system.
    - HVAC system installation quality is pretty good.
    - Full HERS points are earned.

A standard will be born..

- A draft of the standard has been completed and will proceed to public comment in June.
- Preview it here: http://www.resnet.us/blog/wp-content/uploads/2019/03/WD02_RESNETACCA_310-2019-03-24_clean.pdf
- Once the standard is final:
  - An implementation date will be set.
  - Raters will be trained.
  - Software will be updated.

Overview of Standard 310: Standard for Grading the Installation of HVAC Systems

Std. 310: Standard for Grading the Installation of HVAC Systems



Task 1: Design Review

Task 1: Evaluating the design of the forced-air system

1. Rater collects design documentation for the dwelling with the HVAC system under test.
2. Rater reviews design documentation for completeness and compares it to the dwelling to be rated. Key features must fall within tolerances defined in the standard. For example:

Floor Area	Outdoor Design Temps	Insulation Levels
Window Area	# Occupants	Infiltration Rate
Indoor Design Temps	Window SHGC	Ventilation Rate

3. If tolerances are met, proceed to next task. Otherwise stop here.

Task 2: Total Duct Leakage

Task 2: Evaluating the total duct leakage

1. Rater measures total duct leakage according to Std. 380, evaluates the results, and assigns a grade:

Grade	Test Stage	# Returns	Total Leakage Limit
I	Rough-In	< 3	4 CFM/100 sqft or 40 CFM
	Rough-In	≥ 3	6 CFM/100 sqft or 60 CFM
	Final	< 3	8 CFM/100 sqft or 80 CFM
	Final	≥ 3	12 CFM/100 sqft or 120 CFM
II	Rough-In	< 3	6 CFM/100 sqft or 60 CFM
	Rough-In	≥ 3	8 CFM/100 sqft or 80 CFM
	Final	< 3	10 CFM/100 sqft or 100 CFM
	Final	≥ 3	14 CFM/100 sqft or 140 CFM
III	N/A	N/A	No Limit

2. If Grade I or II is achieved, proceed to next task. Otherwise stop here.

Task 3: Blower Fan Airflow

Task 3: Evaluating the Blower Fan Volumetric Airflow

- Raters measure the total volumetric airflow going through the blower fan using one of four test methods:
  A. Pressure Matching
  B. Flow Grid
  C. Flow Hood
  D. OEM Static Pressure Table
- This is just a single measurement. It is not measuring the airflow from each register and summing those.

Task 3: Evaluating the Blower Fan Volumetric Airflow

A. Pressure Matching

1. Measure static pressure created in supply plenum during operation of HVAC system.
2. Turn off HVAC system, connect a fan-flowmeter at the return or at the blower fan compartment.
3. Turn on the HVAC system and the flowmeter fan and adjust to achieve same static pressure in supply plenum.
4. Determine HVAC airflow by recording airflow of flowmeter fan.

Task 3: Evaluating the Blower Fan Volumetric Airflow

B. Flow Grid

1. Measure static pressure created in supply plenum during operation of HVAC system.
2. Install flow grid in filter slot.
3. Measure pressure difference at flow grid and convert to airflow.
4. Re-measure static pressure in same location as Step 1, and correct airflow.

Task 3: Evaluating the Blower Fan Volumetric Airflow

C. Flow Hood

1. Turn on HVAC system.
2. Connect flow hood to return grille.
3. Turn on flow hood and allow reading to stabilize. This may require an additional step to account for back-pressure.
4. Resulting airflow of flow hood determines HVAC airflow.

Task 3: Evaluating the Blower Fan Volumetric Airflow

D. OEM Static Pressure Table

1. Turn on HVAC system.
2. Measure external static pressure of system's supply side and return side.
3. Determine fan-speed setting through visual inspection.
4. Using blower table information, look up total external static pressure and fan-speed setting to determine airflow.

Motor Speed	Tons AC[1]	External Static Pressure, (Inches Water Column)												
		0.1		0.2		0.3		0.4		0.5		0.6	0.7	0.8
		CFM	Rise	CFM	Rise	CFM	Rise	CFM	Rise	CFM	Rise	CFM	CFM	CFM
High	3	1,498	N/A	1,446	N/A	1,368	N/A	1,302	N/A	1,227	N/A	1,145	1,059	954
Med	2.5	1,223	N/A	1,182	N/A	1,153	30	1,099	31	1,051	32	982	901	813
Med-Lo	2	983	35	971	35	945	36	919	37	878	39	813	746	659
Low	1.5	816	42	794	43	758	45	734	46	678	50	637	597	523

Task 4: Blower Fan Watt Draw

Task 4: Evaluating the Blower Fan Watt Draw

- Raters evaluate the watt draw of the blower fan using one of three test methods:
  A. Plug-In Watt Meter
  B. Clamp-On Watt Meter
  C. Utility Meter

Task 4: Evaluating the Blower Fan Watt Draw

A. Plug-In Watt Meter

1. Plug in the watt meter and blower fan equipment into standard electrical receptacle.
2. Turn on equipment in required mode.
3. Record reading from portable watt meter.

Task 4: Evaluating the Blower Fan Watt Draw

B. Clamp-On Watt Meter

1. Turn on equipment in required mode.
2. Connect clamp-on watt meter to measure voltage and current at either the service disconnect or through a service panel (not at breaker panel).
3. Record reading from clamp-on watt meter.

Task 4: Evaluating the Blower Fan Watt Draw

C. Utility Meter

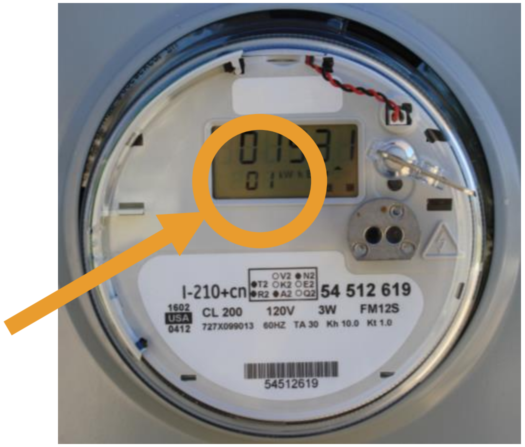
1. Turn off all circuits except air handler's.
2. Turn on equipment in required mode.

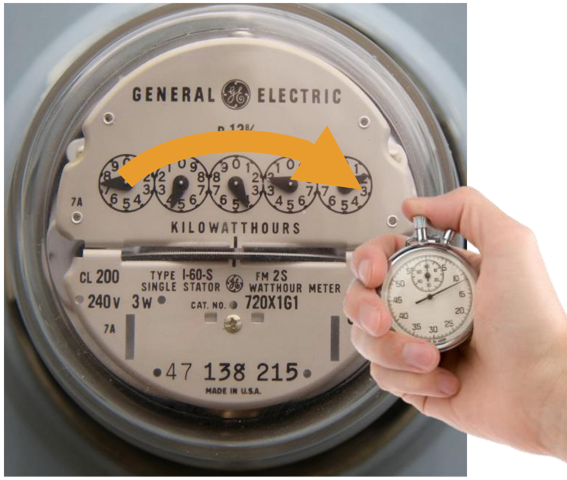
<u>For a digital utility meter:</u>

3. Record watt draw from utility meter.

<u>For an analog utility meter:</u>

3. For 90+ seconds, record the number of meter revolutions and time.
4. Calculate watt draw.





Task 5:
Evaluating Refrigerant Charge

Task 5: Evaluating the Refrigerant Charge

- Raters evaluates the refrigerant charge of the system using one of two test methods:
  A. Non-Invasive Test
  B. Weigh-In Verification - Only for select equipment and conditions

Task 5: Evaluating the Refrigerant Charge

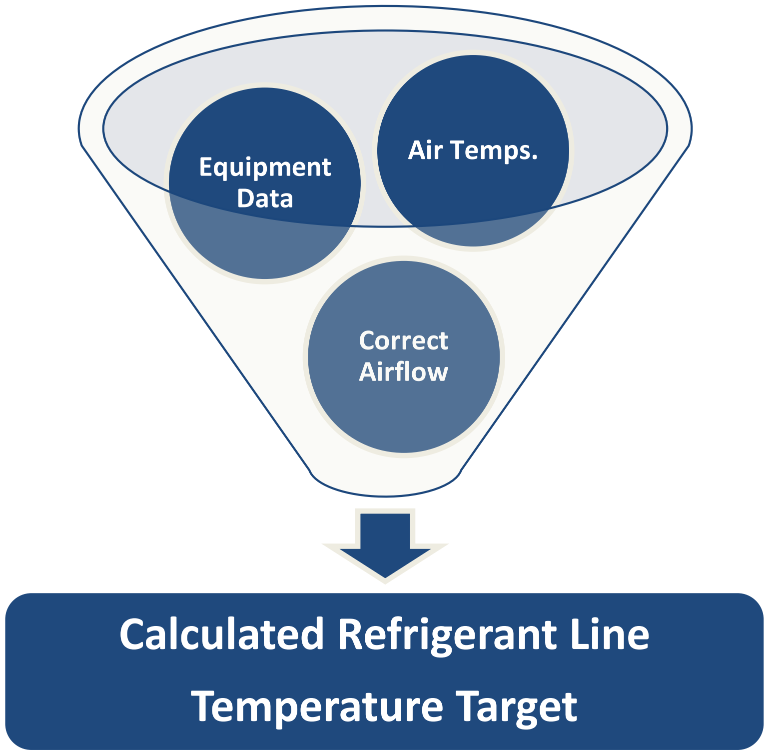
A. Non-Invasive Test

- Non-invasive = No refrigerant gauges
- Triage systems into two bins
  - Grade I – Probably OK
  - Grade III – Not good
- Only flags really bad systems

Temperature Sensor

Task 5: Evaluating the Refrigerant Charge

A. Non-Invasive Test



- How close is the actual refrigerant line temperature to the calculated target?

Task 5: Evaluating the Refrigerant Charge

A. Non-Invasive Test

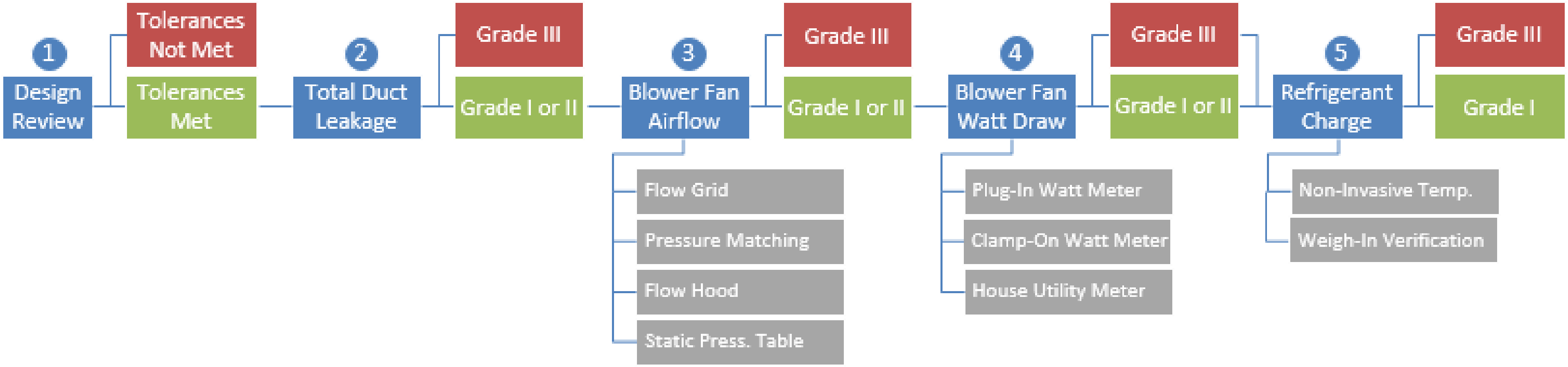
Step 1	**Determine Equipment Characteristics:** Need SEER, and manufacturer specified superheat / subcooling.
Step 2	**Measure Air Temperatures:** Need outdoor air and return air temperatures.
Step 3	**Calculate Target Refrigerant Line Temperatures:** Calculated for suction line and liquid line.
Step 4	**Measure Actual Refrigerant Line Temperatures:** Measuring both suction line and liquid line with a temperature probe.
Step 5	**Compare & Evaluate:** Compare the target line temperatures to the measured temperatures, if they are too far apart, then the system is not properly charged.

Task 5: Evaluating the Refrigerant Charge

B. Weigh-In Verification

1. Contractor provides:
   1. Weight of refrigerant added / removed
   2. Line length and diameter
   3. Default line length from factory charge (usually 15 feet)
   4. Factory supplied charge
   5. Geotagged photo of scale with weight added / removed
2. Rater then:
   1. Measures line length and diameter
   2. Uses lookup table to determine how much refrigerant should have been added / removed
3. Rater verifies the following:
   1. Deviation between lookup and contractor value within tolerance
   2. Location of geotagged photo matches "in the judgment of the party conducting the evaluation" the location of the equipment

Std. 310: Standard for Grading the Installation of HVAC Systems



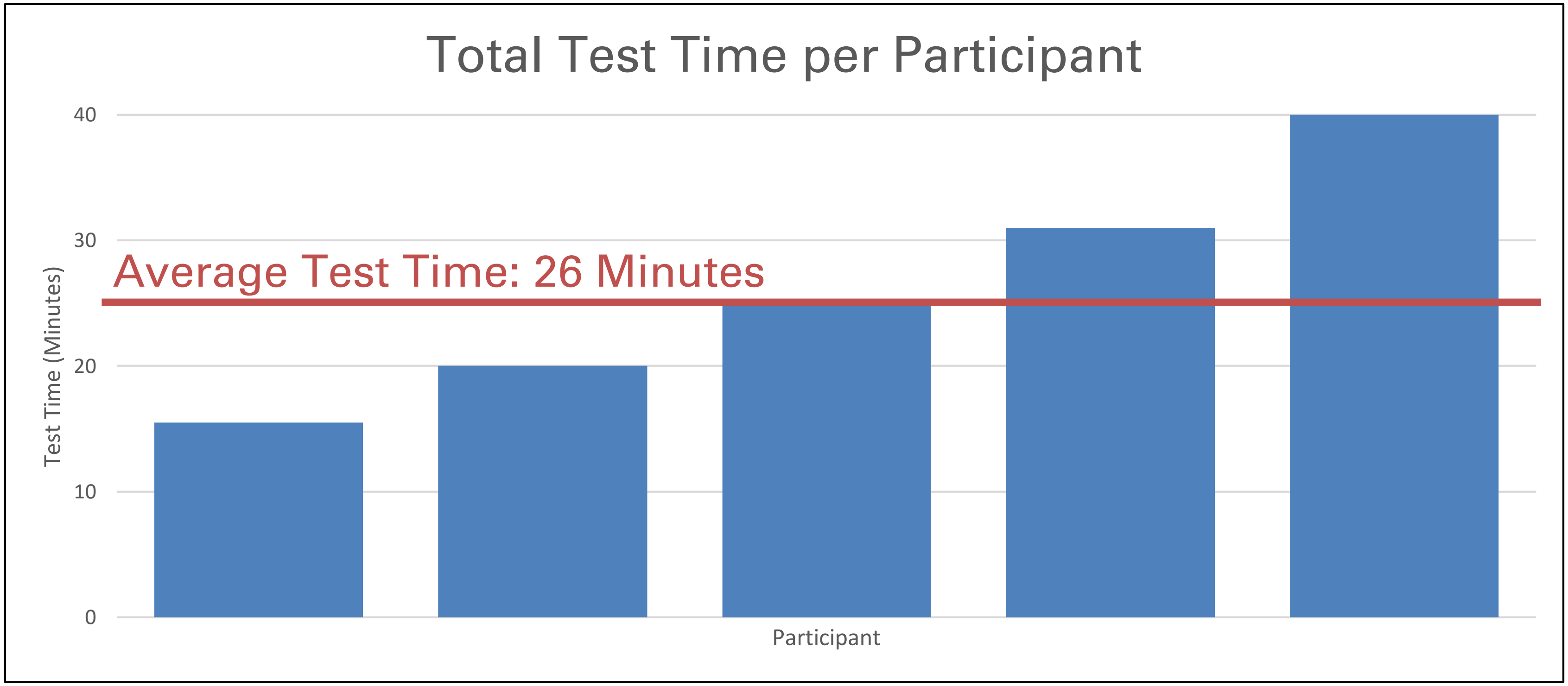
Field Test Results

Field Test: Overview

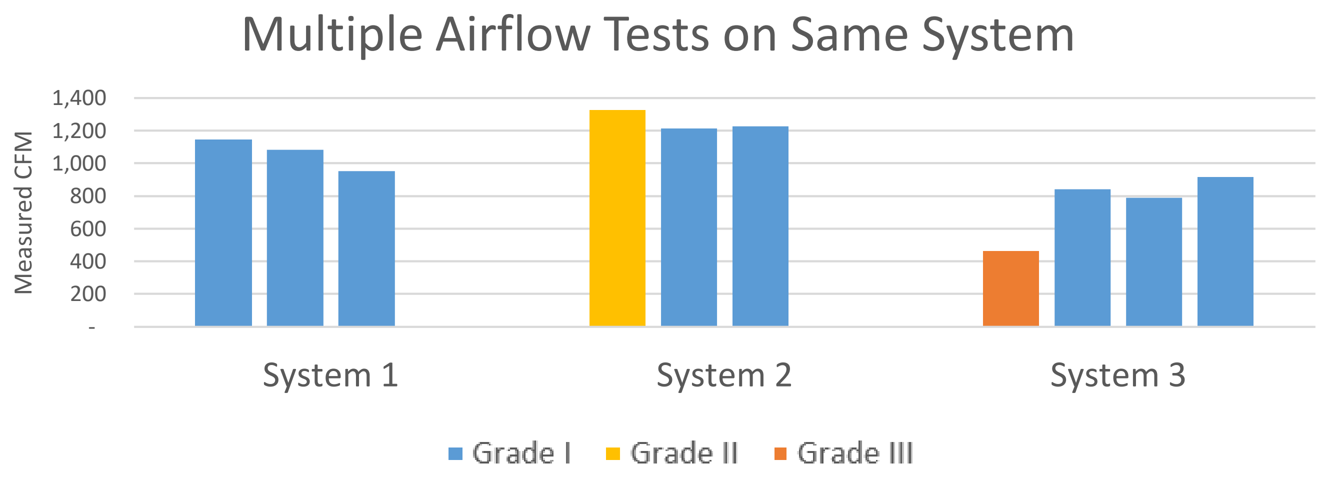
- Select six providers to give field procedures a quick spin:
  - **18 systems** evaluated
  - **63 individual tests** performed

Field Test: Required time to test

- Required HVAC warm-up time is 15 minutes, but Raters can do other tasks during this time. Then they can proceed with testing.
- Average time for all tests among participants was 26 minutes.

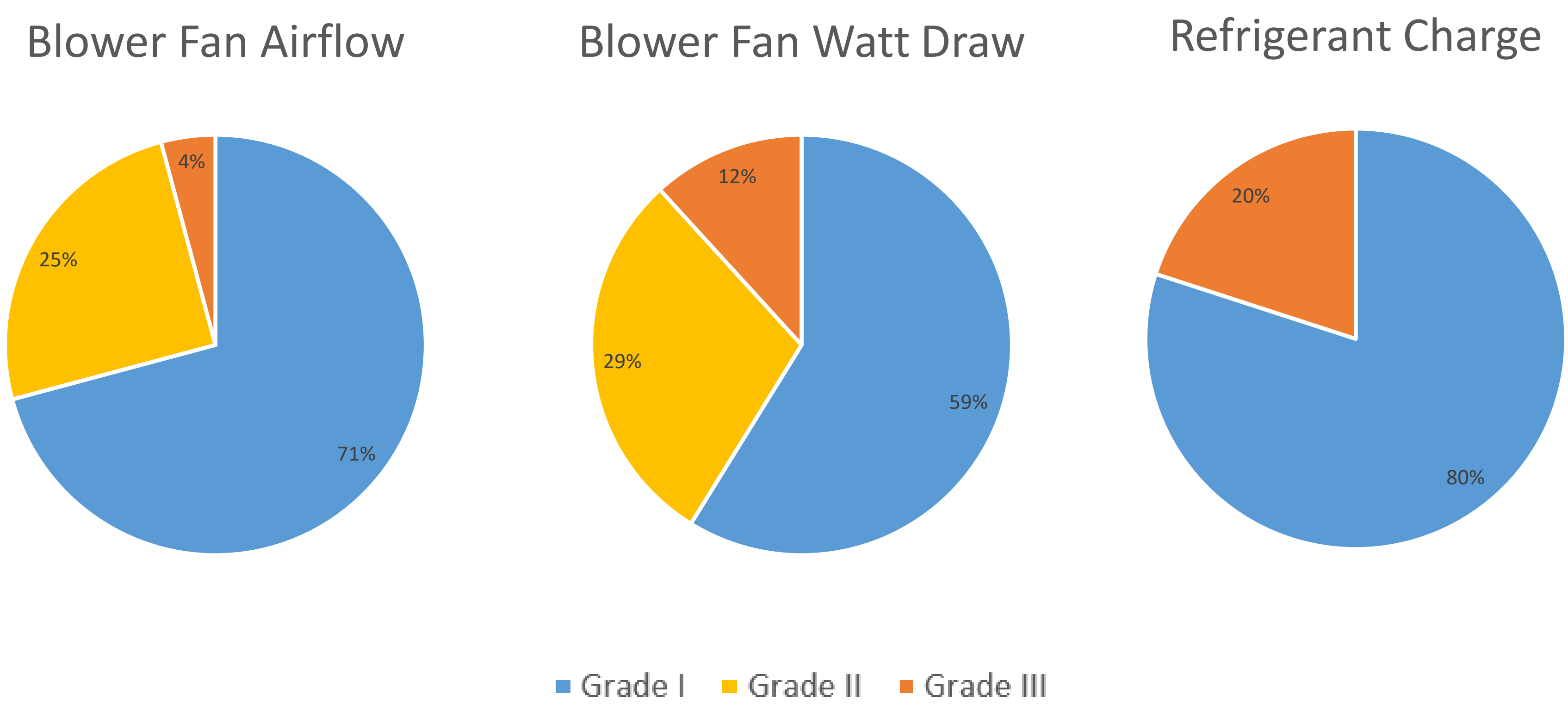


Field Test: Consistency between tests



- These were the first tests done, without training, so this could improve.
- For consistency with a contractor, Raters may need to coordinate on test procedures and equipment.
- However, Grade bins were made to be relatively large to accommodate some variability.

Field Test: What grades were achieved?



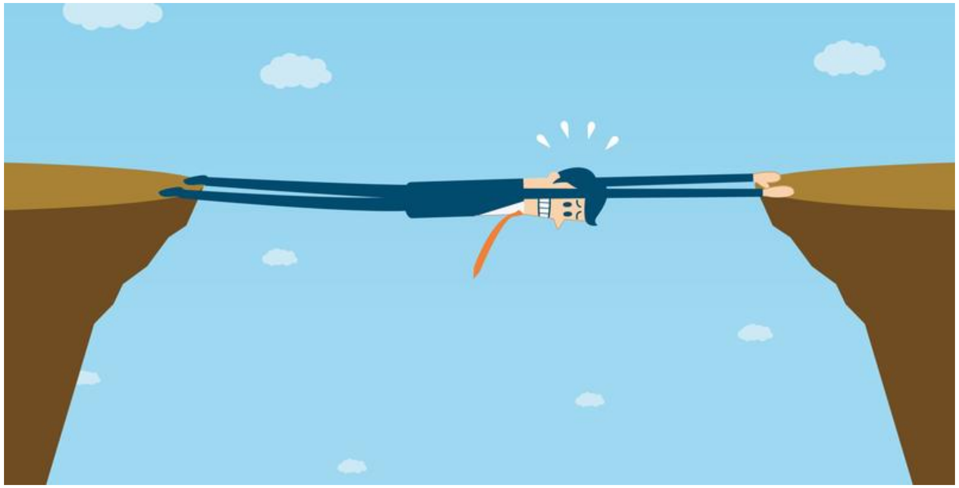
Estimating the ERI Point Potential of Quality Installation

Acknowledgment

- Jon Winkler, Ph.D.
  - Senior Research Engineer
  - Building Energy Science Group
  - National Renewable Energy Laboratory

Overview

<u>Standard 310</u>
(Grading installation quality)



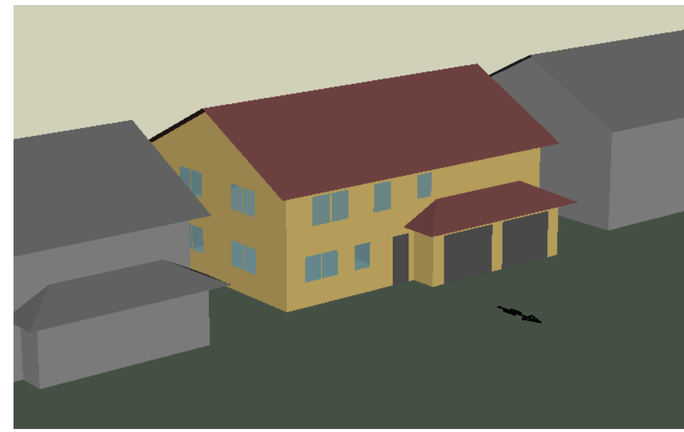
<u>Standard 301</u>
(ERI calculation standard)

- Objectives
  - Implement an approach accounting for HVAC installation defects in building energy simulations
  - Estimate the ERI impact of various defect scenarios

House Parameters

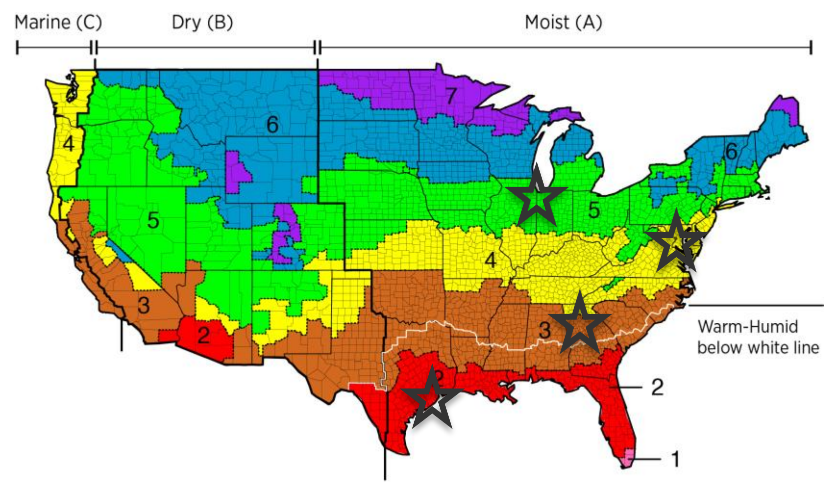
New construction, single-family home

- 3 bed + 2 bath; 2,500 sq. ft
- Construction based on 2009 IECC
- Construction and foundation type varied by climate
- Simulations followed RESNET Standard 301



Simulated Locations

- CZ 2 – Houston, TX
- CZ 3 – Atlanta, GA
- CZ 4 – Washington, DC
- CZ 5 – Chicago, IL



Equipment Assumptions

- **Equipment types**
  - SEER 14 air conditioner and gas furnace
  - SEER 14, 8.2 HSPF central heat pump
- **Equipment assumptions**
  - 0.5 W/cfm fan efficiency
  - Manufacturer recommended airflow is 400 cfm/ton

Defect Scenarios

- Four scenarios were analyzed, where the 'fault' is the % deviation from manufacturer-recommended values:

Parameter	Scenario 1: No Fault	Scenario 2: Airflow Fault	Scenario 3: Charge Fault	Scenario 4: Both Faults
Airflow defect level	0%	-25%	0%	-25%
Refrig. charge defect level	0%	0%	-25%	-25%

- Generally speaking, in Standard 310:
  - Grade III = -25% fault
  - Grade I = 0% fault

Estimated Maximum ERI Impact

System Type	Location		Baseline ERI	Defect Scenario Point Potential		
				-25% Airflow 0% Charge	0% Airflow -25% Charge	-25% Airflow -25% Charge
AC	Houston, TX	CZ 2	71	1.5	2.9	4.5
	Atlanta, GA	CZ 3	76	1.2	1.6	2.9
	Washington, DC	CZ 4	78	0.9	1.1	2.1
	Chicago, IL	CZ 5	80	0.5	0.3	0.8
HP	Houston, TX	CZ 2	72	1.9	4	6.0
	Atlanta, GA	CZ 3	75	2.8	4.7	7.0
	Washington, DC	CZ 4	77	3.3	4	6.7
	Chicago, IL	CZ 5	74	3.5	3.6	6.1

- Caveats:
  - For homes better than 2009 IECC, smaller point potential
  - This is the max potential. Many homes will get partial credit.
  - Fine-tuning may still occur in Standard 310

Modeling Summary

- Previous work by RESNET Working Group:
  - Initial estimate of point potential using cursory modeling.
  - Air conditioners:
    - Hot climates: ~3 points
    - Mixed climates: ~2 points
    - Cold climates: ~1 point
  - Heat pumps: Non-intuitive low potential in cold climates.
- NREL's approach:
  - Shows similar trends for air conditioners, but with higher potential, partially due to lower efficiency home.
  - More intuitive results for heat pumps.
  - Lays groundwork for software programs to ensure installation quality impacts get modeled consistently.

Questions?