Checking Your Work: Properly Installed HVAC in New Homes

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Description

Many AC's and heat pumps are installed with faults that impact both their performance and efficiency. Come to this webinar to learn about a new RESNET/ACCA/ANSI standard with three simple field tests that can help a builder ensure they're getting what they've paid for. Not only can this make for happier homeowners, fewer service calls, and lower utility bills, it can also unlock new points for homes with a HERS/ERI rating.

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Learning Objectives

1. Understand why HVAC installation faults are commonplace and how they can impact both the efficiency of the equipment and the comfort of occupants.
2. Learn about a new RESNET/ACCA/ANSI standard that addresses this problem, including three field tests that can help a builder ensure their HVAC systems are performing properly.
3. Learn how this standard is integrated into ANSI/RESNET/ICC 301, the standard that underlies HERS and ERI ratings, which was used to rate over 4,000 homes in Pennsylvania in 2019 alone.
4. Understand three ways that this new standard will improve the homes you build.

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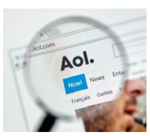
Installation defects in HVAC systems are commonplace



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Installation defects in HVAC systems are commonplace

- Improper airflow:
  - Average airflow ~20% below target. Blasnik et al. (1995)
  - Average airflow 14% below design. Proctor (1997)
  - Measured airflow ranging from 130 - 510 CFM / ton. Parker (1997)
  - 70% of units had airflow < 350 CFM / ton. Neme et al. (1999)
  - Improper airflow in 44% of systems. Mowris et al. (2004)

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Installation defects in HVAC systems are commonplace

- Incorrect refrigerant charge:
  - In 57% of systems. Downey/Proctor (2002)
  - In 62% of systems. Proctor (2004)
  - In 72% of systems. Mowris et al. (2004)
  - In 82% of systems. Proctor (1997)

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Installation defects in HVAC systems are commonplace

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	New	30	345	50%		8%	Est @ 33% combined charge/air flow correction benefits
Blasnik et al. 1995b	CA	New	10	319	90%			
Blasnik et al. 1996	AZ	New	22	344	64%	29%	10%	Est @ 33% combined charge/air flow correction benefits
Hammarlund et al. 1992	CA	New	12			30%	10%	Single family results
Hammarlund et al. 1992	CA	New	66		76%	14%	12%	
Neme et al. 1997	MD	New	25	340				
Palani et al. 1992	n.a.	n.a.	n.a.				4%	
Parker et al. 1997	FL	Both	27	270	89%	7%	10%	
Proctor & Pernick 1992	CA	Existing	175		44%			
Proctor 1991	CA	Existing	15			33%		
Proctor et al. 1995a	CA	Existing	30	300	80%	11%		
Rodriguez et al. 1995	n.a.	n.a.	n.a.				2%	
Rodriguez et al. 1995	n.a.	n.a.	n.a.				10%	
VEIC/PEG 1997	NJ	New	52	372		30%	7%	
Average				327	70%	22%	8%	

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.				6%	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%	

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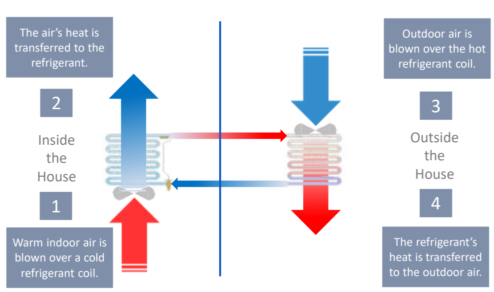
Installation defects in HVAC systems are commonplace



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ANSI / RESNET / ACCA Std. 310: Overview

- New standard developed to grade the installation quality of HVAC systems – ANSI / RESNET / ACCA Std 310.
- Std 310 has been incorporated by reference into ANSI/RESNET/ICC Std 301, allowing properly installed HVAC to get credit in HERS/ERI ratings.
- Primarily designed for raters to use when completing an energy rating:
  - ~ 6,600, or 24%, of new homes got an energy rating in Pennsylvania last year
  - Going forward, all rated homes could easily incorporate this HVAC grading standard
- Because the ENERGY STAR single-family new homes program requires an energy rating, it will also benefit.

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ANSI / RESNET / ACCA Std. 310: Guiding Principles

- Take a 'carrot' rather than a 'stick' approach.
- Reward incremental improvement.
- Include procedures applicable to both Rater and HVAC professionals.
- Ensure the procedures provide value in and of themselves.

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ANSI / RESNET / ACCA Std. 310: Grading Concept

- Follow the insulation quality-installation model:
  - Grade III: The default. No assessment. No penalty and no credit.
  - Grade II: Assessment completed and the system is ok. Partial credit.
  - Grade I: Assessment completed and the system is very good. Full credit.

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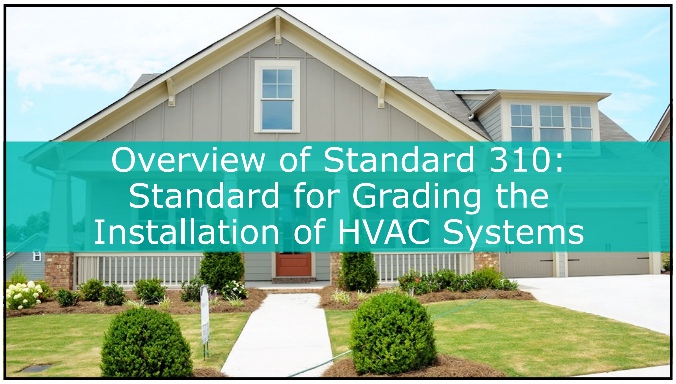

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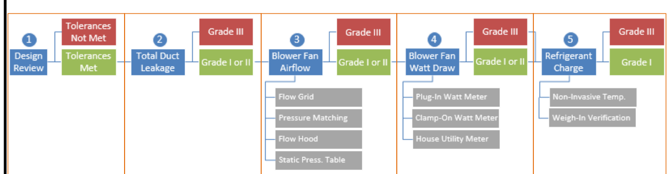
Std. 310: Standard for Grading the Installation of HVAC Systems



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Task 1: Evaluating the design

1. Rater collects design documentation for the dwelling with the HVAC system being tested.
2. Rater reviews design documentation for completeness and compares it to the dwelling. Key features must fall within defined tolerances. For example:

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

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

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Task 2: Evaluating 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 (CFM per 100 ft^2 or Total CFM)
I	Rough-In	< 3	4 or 40 total
		≥ 3	6 or 60 total
	Final	< 3	8 or 80 total
		≥ 3	12 or 120 total
II	Rough-In	< 3	6 or 60 total
		≥ 3	8 or 80 total
	Final	< 3	10 or 100 total
		≥ 3	14 or 140 total
III	N/A	N/A	No Limit

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

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Task 3: Evaluating the Blower Fan Volumetric Airflow

- Raters measure the total airflow going through the blower fan using one of four test methods:
  A. Flow Hood
  B. Flow Grid
  C. Pressure Matching
  D. OEM Static Pressure Table
- This is just a single measurement. It is not measuring the airflow from each register and summing those.
- The measured airflow is compared to the design airflow. The closer the better. This difference is used to assign Grade I, II, or III.
- If Grade I or II is achieved, proceed to next task. Otherwise stop here

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Task 3: Evaluating the Blower Fan Volumetric Airflow

A. 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.

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Task 3: Evaluate the Blower Fan Airflow

A. Flow Hood

Pros	Cons
Accurate: +/- 3%	Can be heavy/unwieldy
Easy to use	Can be sensitive to placement
Does not require hole in supply plenum	Can be expensive
	Will not always fit around air inlet

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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.

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Task 3: Evaluate the Blower Fan Airflow

B. Flow Grid

Pros	Cons
Easy/simple for many systems	Multiple filter slots in a single system require multiple flow grids
Can work at higher flows	Need to make sure a good seal is achieved around the plate perimeter
	Slightly less accurate +/- 7%
	Requires hole in supply plenum

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Task 3: Evaluating the Blower Fan Volumetric Airflow

C. 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.

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Task 3: Evaluate the Blower Fan Airflow

C. Pressure Matching

Pros	Cons
Uses equipment many Raters already own	Can't reach high flows for big systems: needs extrapolation
Accurate: +/- 3%	Need at least one large return duct or must connect at equipment
	Requires hole in supply plenum

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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

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Task 3: Evaluate the Blower Fan Airflow

D. OEM Static Pressure Table

Pros	Cons
Inexpensive equipment	Rater required to get OEM Blower Table for installed equipment
Works for systems of all sizes and airflows	Needs carefully-placed hole in supply-side and return-side, sometimes in equipment housing

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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
- The airflow and watt draw is used to calculate fan efficiency. The more efficient, the better. This is used to assign Grade I, II, or III.
- Regardless of grade, you can proceed to next task.

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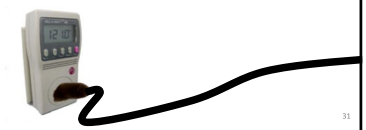
Task 4: Evaluating the Blower Fan Watt Draw

A. Plug-In Watt Meter

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



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Task 4: Evaluate Blower Fan Watt Draw

A. Plug-In Watt Meter

Pros	Cons
Simple	Not usable with hard-wired equipment
Direct measurement of equipment	

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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.

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Task 4: Evaluate Blower Fan Watt Draw

B. Clamp-On Watt Meter

Pros	Cons
Useable with hardwired equipment that has service panel or service disconnect	Requires proper training and safety equipment
Direct measurement of equipment	

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Task 4: Evaluating the Blower Fan Watt Draw

C. Utility Meter

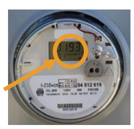
1. Turn off all circuits except air handler's.
2. Turn on equipment in required mode.

For a digital utility meter:

3. Record watt draw from utility meter.

For an analog utility meter:

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



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Task 4: Evaluate Blower Fan Watt Draw

C. Utility Meter

Pros	Cons
Works with all equipment	Indirect measurement, and some meters are less sensitive to low watt draw.
No new equipment needed	Turning off all other circuits can be disruptive

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Task 5: Evaluate Refrigerant Charge

- Raters evaluates the refrigerant charge of the system using one of two test methods:
  - A. Non-Invasive Method
  - B. Weigh-In Verification Method

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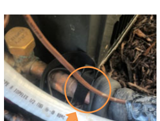
Task 5: Evaluate Refrigerant Charge

A. Non-Invasive Method

- 'Non-invasive' means no gauges connected to refrigerant system.
- Instead, the temperature of the air and refrigerant lines are used.
- Triage systems into two bins:
  - Grade I – Charge is okay
  - Grade III – Charge is not okay

Refrigerant Gauges Not Connected



Temperature Sensors Used Instead

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Task 5: Evaluate Refrigerant Charge

A. Non-Invasive Method

1. Determine SEER and mfr-specified superheat / subcooling value.
2. Measure outdoor air and return air temperatures.
3. Use to calculate target temperatures for suction line and liquid line.
4. Measure actual temperatures for suction line and liquid line.
5. Compare target to actual temperatures; if they are close enough, then the system is properly charged.

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Task 5: Evaluate Refrigerant Charge

A. Non-Invasive Method

Pros	Cons
No refrigerant handling certification needed	New procedure to learn
No risk of refrigerant contamination and leaks; less Rater liability	Can't be used with extreme outdoor temps
	Can't be used with mini/multi-splits

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Task 5: Evaluate Refrigerant Charge

B. Weigh-In Verification Method

- The weigh-in verification method can be used year-round and it must be used for:
  - Extreme outdoor conditions.
  - Mini/multi-split systems.
- This method is primarily a document review rather than a performance test.

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Task 5: Evaluate Refrigerant Charge

B. Weigh-In Verification Method

- Contractor provides:
  - A. Weight of refrigerant added / removed
  - B. Line length and diameter
  - C. Default line length from factory charge (usually 15 feet)
  - D. Factory supplied charge
  - E. Geotagged photo of scale with weight added / removed
- Rater then:
  1. Measures line length and diameter
  2. Uses lookup table to determine how much refrigerant should have been added / removed
  3. Verifies the deviation between the lookup and contractor values are within tolerance
  4. Verifies location of geotagged photo matches the location of the equipment

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Task 5: Evaluate Refrigerant Charge

B. Weigh-In Verification Method

Pros	Cons
No refrigerant handling certification needed	Requires information from contractor
Works at any outdoor temperature	Not a true performance test

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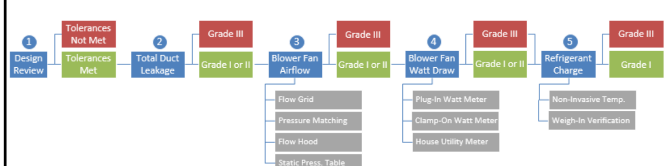
Std. 310: Standard for Grading the Installation of HVAC Systems



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Field Test: Overview

- Select six providers to give field procedures a quick spin:
  - **18 systems** evaluated
  - **63 individual tests** performed
- Only cursory training was provided
- Feedback helped finetune the standard before completion

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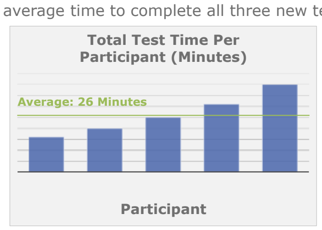
Field Test: Time to Test

- HVAC is required to run for 15 minutes prior to testing.
- However, Raters can do other tasks during this time.
- Once started, average time to complete all three new tests was **26 minutes**.



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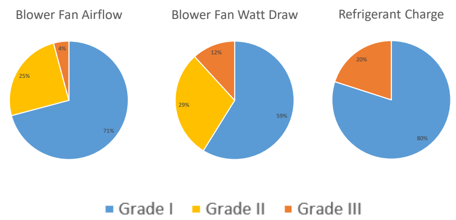
Field Test: What Grades Were Achieved?



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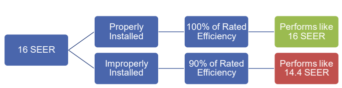
Properly-installed HVAC maintains efficiency



- Rewarded with new points in your energy rating.
- Rewarded with better tax credit compliance.

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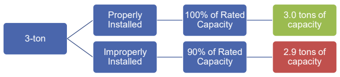
Properly-installed HVAC maintains capacity



- Maintaining capacity means more cooling and heating delivered.
- Rewarded with better comfort and durability.

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HVAC grading benefits for..

- Builders – Energy ratings, tax credit, comfort, durability.
- Raters – Valuable new service for any energy rated home.
- Utility Programs – Energy and demand benefits.
- HVAC Manufacturers – Rewarded for features that ease installation.
- ENERGY STAR – Integrates most program requirements into a standard rating.

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ENERGY STAR (With HVAC Grading)

Efficiency Feature	Good energy rating with features locked in

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ENERGY STAR (With HVAC Grading)

Comfort Feature | Complete Thermal Enclosure System

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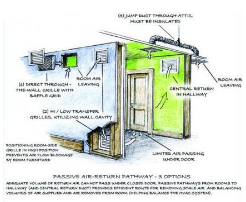
ENERGY STAR (With HVAC Grading)

Comfort Feature | Bedroom comfort vents



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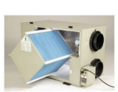
ENERGY STAR (With HVAC Grading)

Air Quality Feature | Whole-House Fresh Air System



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ENERGY STAR (With HVAC Grading)

Air Quality Feature | Kitchen & Bath Fans That Work Well

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ENERGY STAR (With HVAC Grading)

Air Quality Feature | MERV 6+ Filter, Properly Installed

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ENERGY STAR (With HVAC Grading)

Air Quality Feature | Combustion Safety

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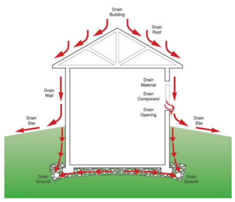
ENERGY STAR (With HVAC Grading)

Durability Feature	Complete Water Management System



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ENERGY STAR (With HVAC Grading)

ENERGY STAR

Energ y Ratin g

Efficiency	• Good energy rating with features locked
Comfort Features	• Complete thermal enclosure system • Bedroom comfort vents
Air Quality Features	• Whole-house fresh air system • Kitchen and bath fans that work well • MERV 6+ filter, properly installed • Combustion safety
Durability Feature	• Complete water management system

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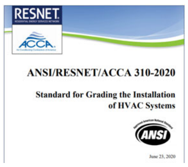
1. Standard 310: HVAC Grading Standard

- **What is this?** Defines how the Rater completes the design review, field tests, and designates the grade.
- View standard at:
  ✔ **https://www.resnet.us/about/standards/resnet-ansi/**
- **Status:** Complete!



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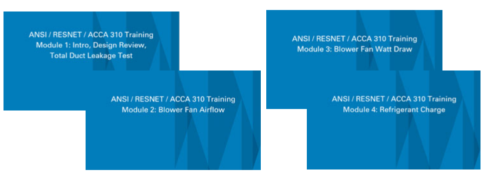
2. Training & Evaluation

- **What is this?** Trains and evaluates Raters and RFI's on new requirements in Std. 310, prior to use.
- ✔ **Status:** Complete and available for Raters today!



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3. Standard 301: Energy Ratings Update

- **What is this?** Integrates Std. 310 into the overall rating process; updates definitions, calculations, minimum rated features, and on-site inspection protocols.
- ✔ **Status:** Complete!

ANSI/RESNET/ICC 301-2019 Addendum B-2020

Clarifications, HVAC Quality Installation Grading, and Dehumidification

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4. Rating software updates

- **What is this?** Rating software vendors must add the inputs and calculations to support Std 310.
- **Status:** Almost complete! Updates to Ekotrope and EnergyGauge are available now; Rem/Rate coming soon.

ekotrope

EnergyGauge®
Energy and Economic Analysis Software

REM/*Rate*™

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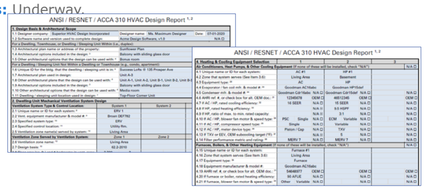
5. HVAC Design Report Templates

- **What is this?** Create new Std. 310 HVAC design report and ENERGY STAR supplement and integrate into Wrightsoft, RHVAC, and EnergyGauge.
- **Status:** Underway.



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Summary of Timeline for Use

- Standard 310 can be used today, with the following caveats:
  - Raters and RFI's working under RESNET must complete training and graded field evaluation prior to use.
  - Recommend waiting until the Std. 310 HVAC design report template is integrated into design software for energy ratings.
  - Recommend waiting until ENERGY STAR design report supplement is complete and integrated into design software for ENERGY STAR homes.

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Summary

- Installation defects in HVAC systems are commonplace.
- Standard 310 is a new standard for evaluating the design and installation quality of HVAC systems.
- This standard can:
  - Improve the performance of your HVAC systems,
  - Earn new points in an energy rating and assist with tax credit compliance,
  - Make it easier to certify ENERGY STAR single-family new homes.
- To learn more, visit https://www.resnet.us/about/standards/resnet-ansi/:
  - Download the standard under 'Approved ANSI/RESNET Standards'
  - Download the design report template and an Excel-based tool for using the standard under 'Other Resources' / 'Calculators And Tools'.

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