Checking Your Work:
Properly Installed HVAC in High-Performance Homes

Home Efficiency Forum

October 18, 2019

United States Environmental Protection Agency

Installation defects in HVAC systems are commonplace

Introduction

Installation defects in HVAC systems are commonplace

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)

Installation defects in HVAC systems are commonplace

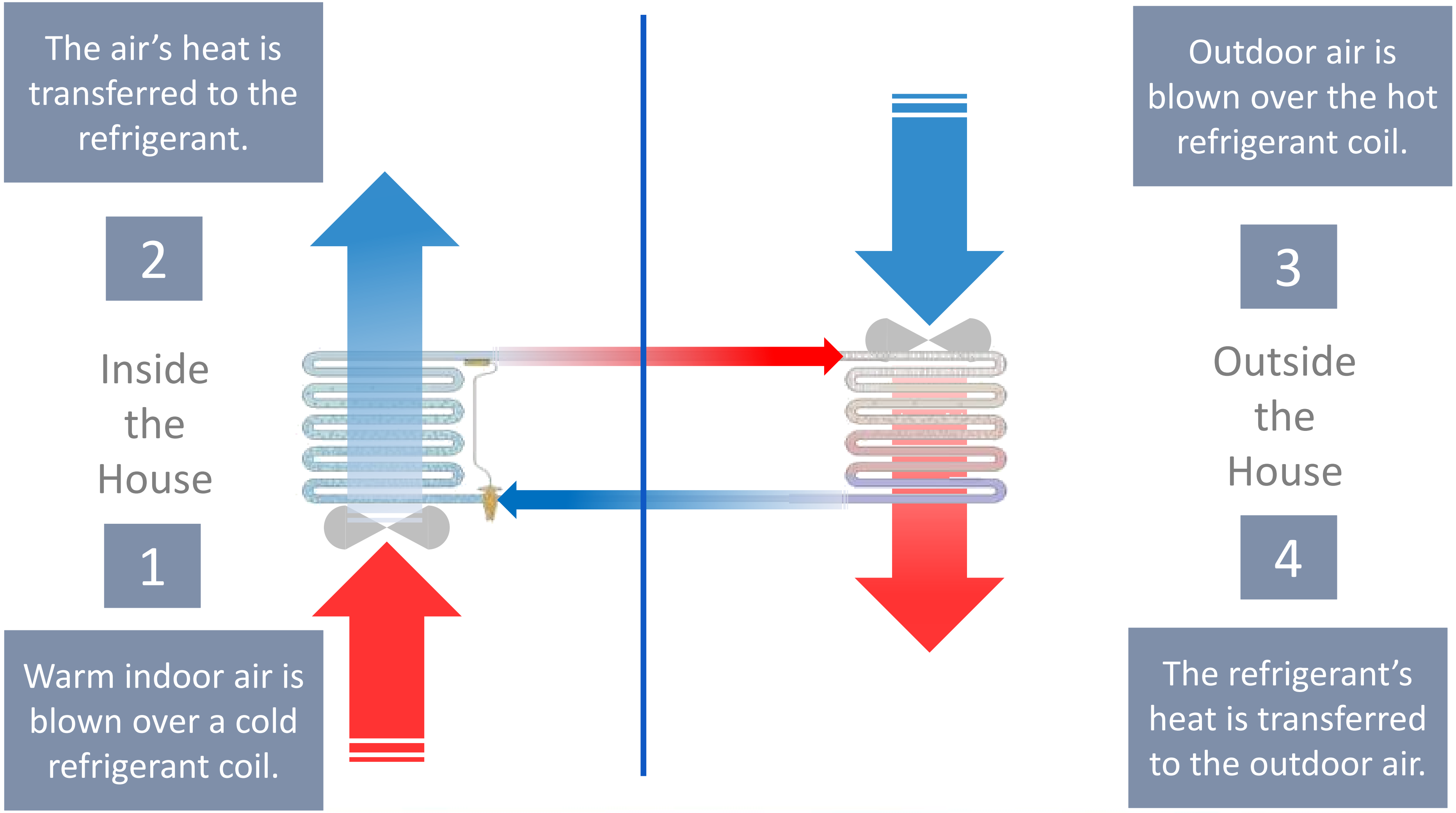
- Incorrect refrigerant charge:
  - In 57% of systems. Downey/Proctor (2002)
  - In 62% of systems. Proctor (2004)
  - In 72% of systems. Mowris et al. (2004)
  - In 82% of systems. Proctor (1997)

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.				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%	

Installation defects in HVAC systems are commonplace



RESNET/ACCA Std. 310: Guiding Principles

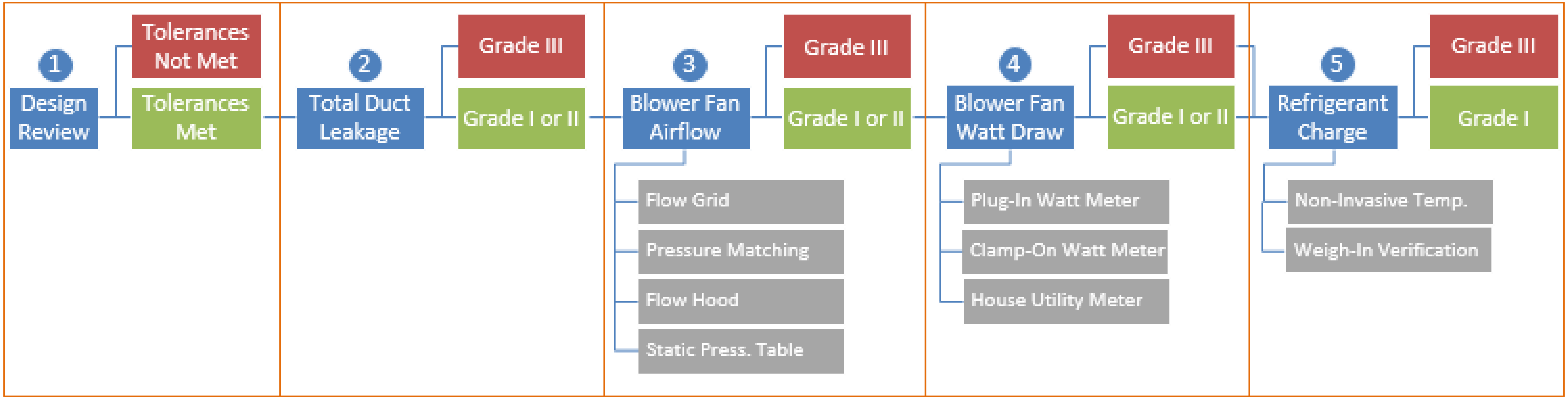
- Take a ‘carrot’ rather than a ‘stick’ approach.
- Reward incremental improvement.
- Include procedures applicable to both Rater and HVAC professionals.
- Ensure the procedures provide value in and of themselves.

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.

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. Flow Grid
  B. OEM Static Pressure Table
  C. Pressure Matching
  D. Flow Hood
- This is just a single measurement. It is not measuring the airflow from each register and summing those.

Note: Dan rearranged the order to more closely align with NW Rater's current approaches

Task 3: Evaluating the Blower Fan Volumetric Airflow

A. 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

A. 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

Task 3: Evaluating the Blower Fan Volumetric Airflow

B. 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 3: Evaluating the Blower Fan Volumetric Airflow

B. 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

Task 3: Evaluating the Blower Fan Volumetric Airflow

C. Pressure Matching

D. Flow Hood

Task 3: Evaluating the Blower Fan Volumetric 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

D. 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

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 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.

Task 4: Evaluating the Blower Fan Watt Draw

A. Plug-In Watt Meter

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

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

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	

Task 4: Evaluating the Blower Fan Watt Draw

C. Utility Meter

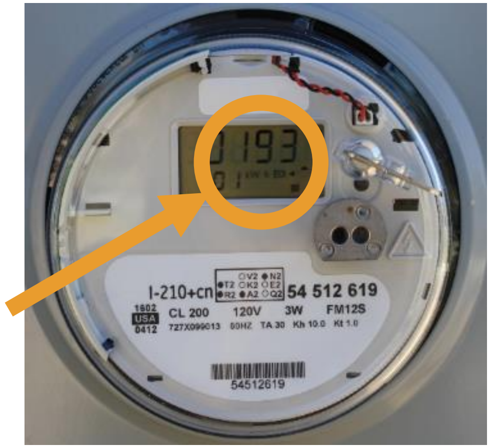
1. Turn off all circuits except air handler's.
2. Turn on equipment in required mode.

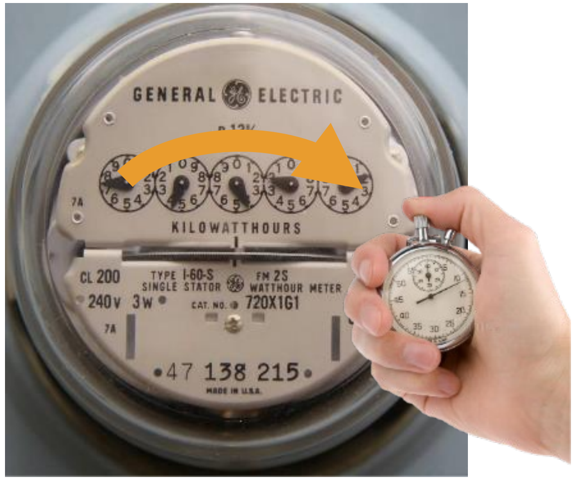
For a digital utility meter:

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.





Task 4: Evaluating the 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

Task 4, the watt draw task, is the only one where you're not required to meet a threshold to proceed. So a Rater could do Task 1-3, skip 4 and take the Grade III default for watt draw, and then proceed to Task 5 and get Grade I for refrigerant charge.

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 Method
  B. Weigh-In Verification Method - Only for select equipment & conditions

Task 5: Evaluating the 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

Task 5: Evaluating the 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.

Task 5: Evaluating the Refrigerant Charge

A. Non-Invasive Method

Pros	Cons
No refrigerant handling certification needed	New procedure to learn
No risk of refrigerant contamination and leaks	Minimum outdoor air temperature limit
Less Rater liability	

Task 5: Evaluating the Refrigerant Charge

B. Weigh-In Verification Method

- Non-invasive method can't be used for:
  - All outdoor conditions.
  - Mini/multi-split systems.
- In such cases, the weigh-in verification method is used instead.
- Method is primarily a document review rather than a performance test.

Task 5: Evaluating the 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

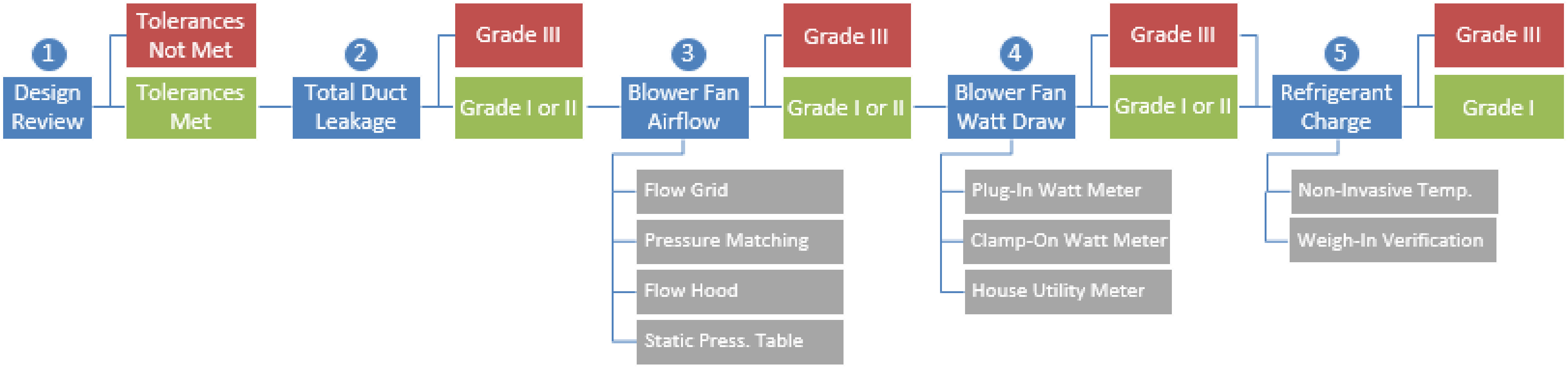
- Rater then:
  1. Measures line length and diameter
  2. Uses lookup table to determine how much refrigerant should have been added / removed
  3. Verifies the deviation between the lookup and contractor values are within tolerance
  4. Verifies location of geotagged photo matches the location of the equipment

Task 5: Evaluating the Refrigerant Charge

B. Weigh-In Verification Method

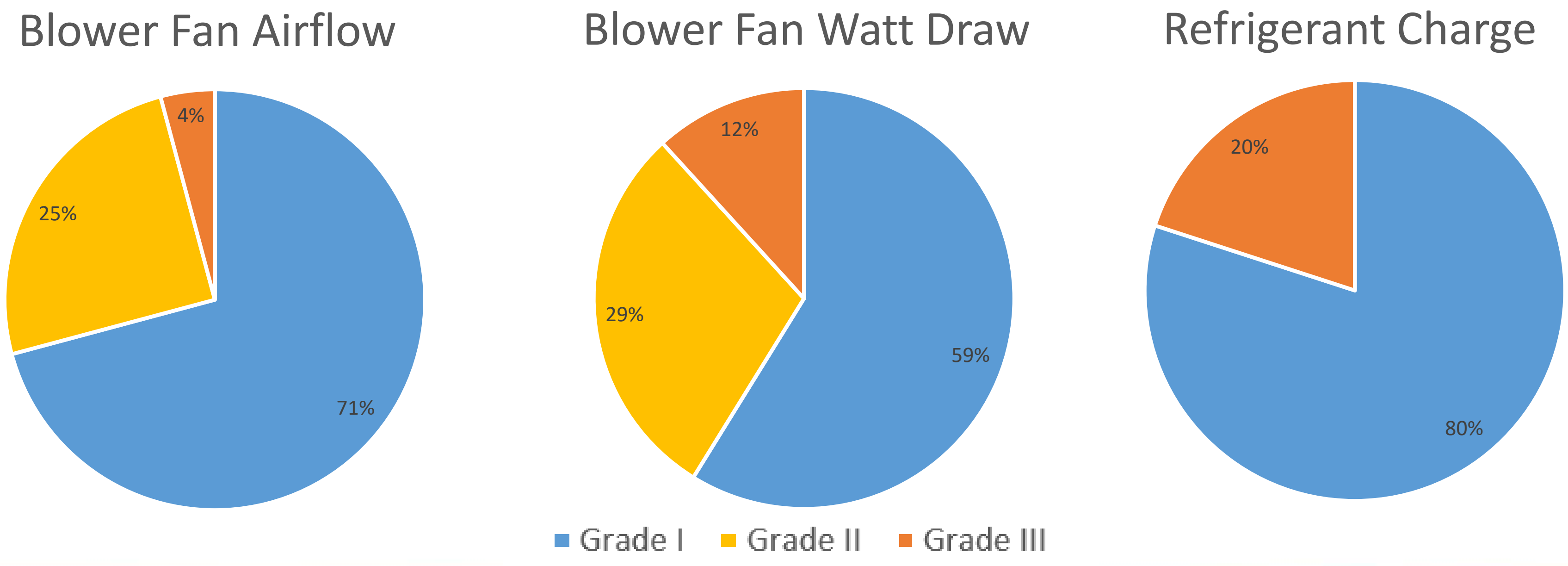
Pros	Cons
No refrigerant handling certification needed	Requires information from contractor
Works at any outdoor temperature	Not a true performance test

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



Field Test

- Six providers evaluated **18 systems** and performed **63 individual tests**.
- Required HVAC warm-up time is 15 minutes, but Raters can do other tasks during this time. After that, average time for all tests was **26 minutes**.
- Most systems achieved a **Grade I designation**:



How HVAC Grading Will Improve Your Homes

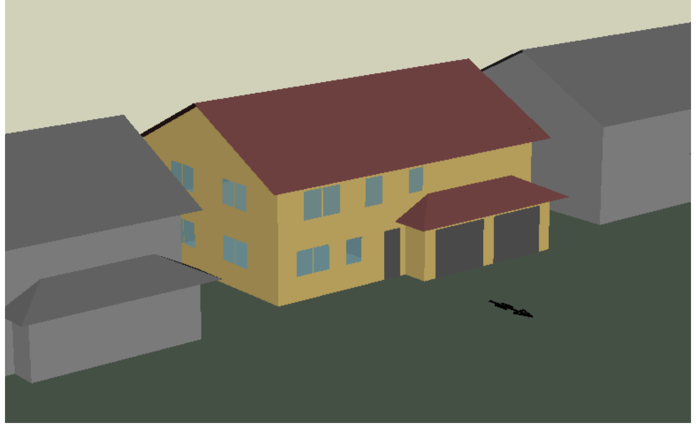
#1 - Extra Points in Energy Ratings

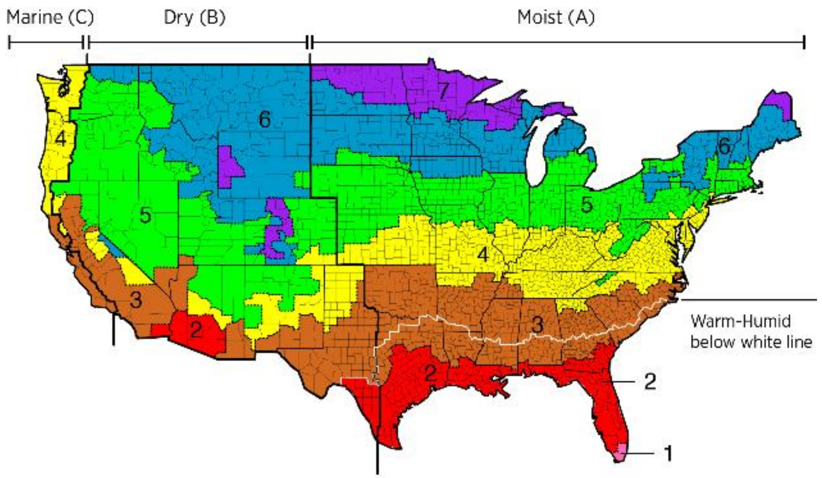
Acknowledgment

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

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		Max. Point Potential for Going from Scenario 4 (Grade III) to Scenario 1 (Grade I)
AC	Houston, TX	CZ 2	4.5
	Atlanta, GA	CZ 3	2.9
	Washington, DC	CZ 4	2.1
	Chicago, IL	CZ 5	0.8
HP	Houston, TX	CZ 2	6.0
	Atlanta, GA	CZ 3	7.0
	Washington, DC	CZ 4	6.7
	Chicago, IL	CZ 5	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:

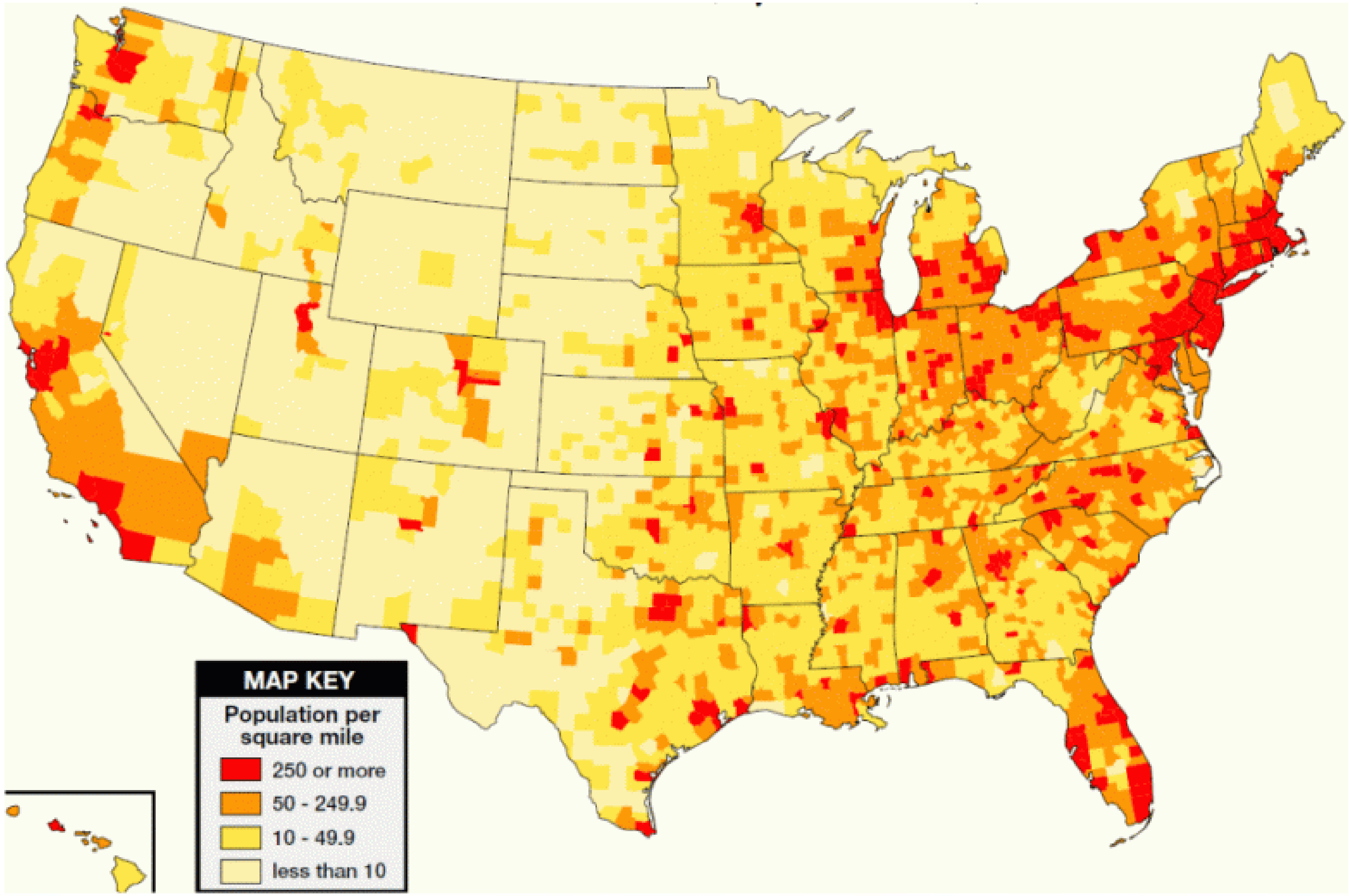
- Initial estimate of point potential using cursory modeling.
- Air conditioners:
  - Hot climates: ~3 points
  - Mixed climates: ~2 points
  - Cold climates: ~1 point
- Heat pumps: Non-intuitive low potential in cold climates.

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.

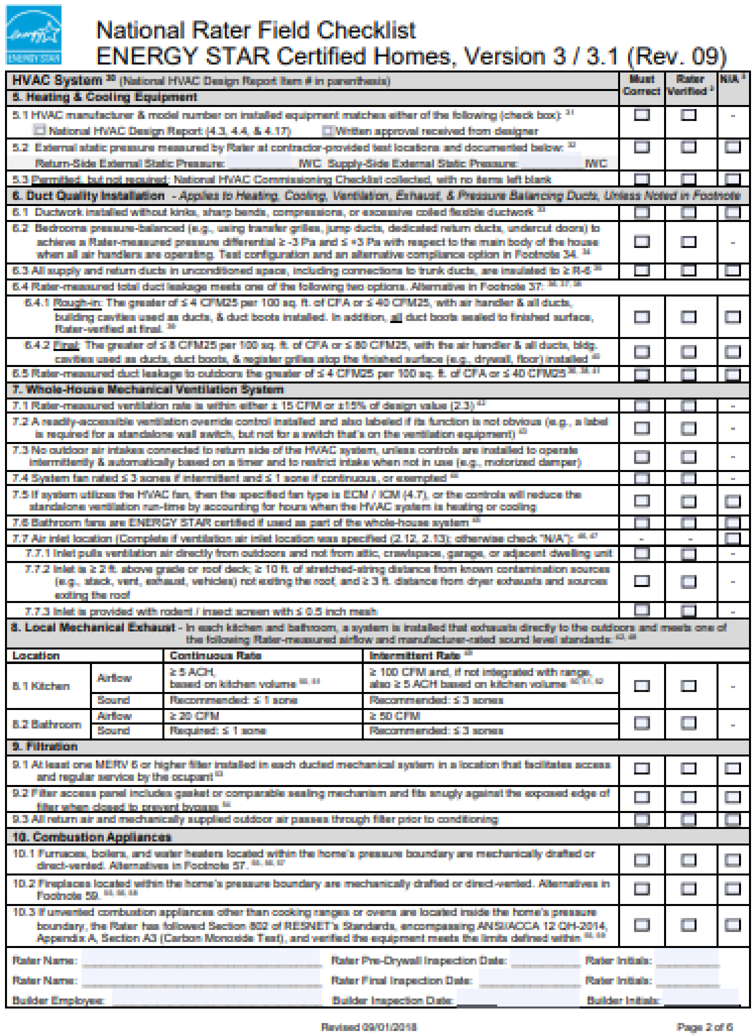
#2 - Provides Alternative to Requirement for Credentialed Contractor

Service providers are harder to find in small markets



HVAC grading provides a new alternative

- You may still choose to work with credentialed contractors.
- But like duct leakage, standard Rater procedures can be used in lieu of a credential.


National Rater Field Checklist
ENERGY STAR Certified Homes, Version 3 / 3.1 (Rev. 09)
Revised 09/01/2018
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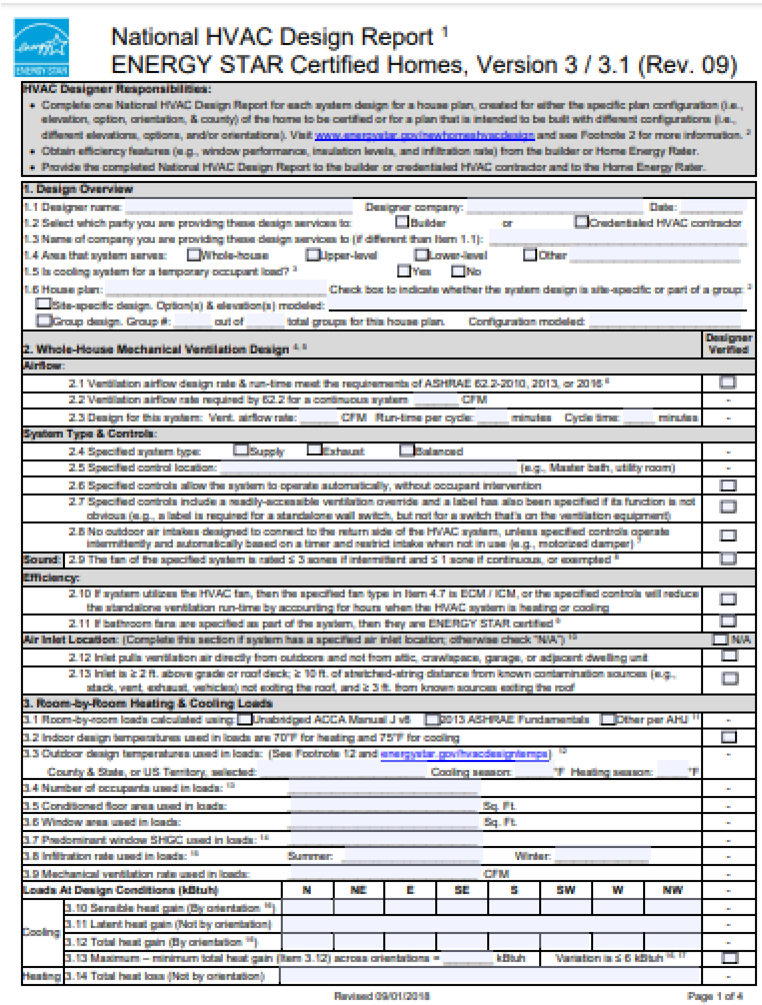
National HVAC Design Report
ENERGY STAR Certified Homes, Version 3 / 3.1 (Rev. 09)
Revised 09/01/2018
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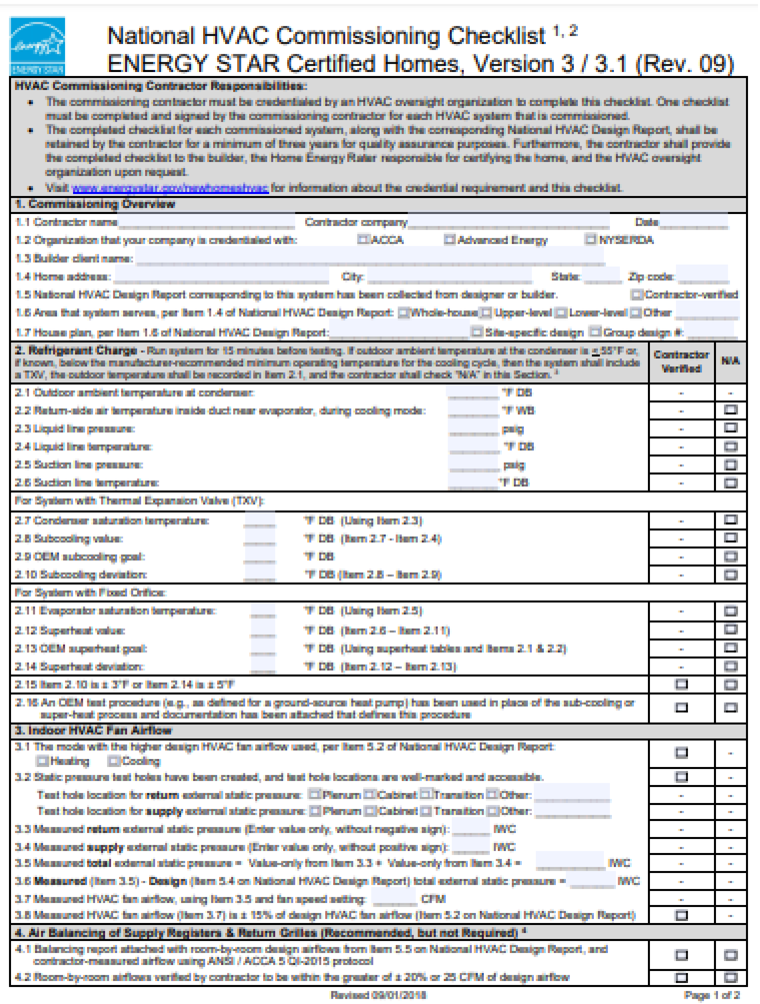
National HVAC Commissioning Checklist
ENERGY STAR Certified Homes, Version 3 / 3.1 (Rev. 09)
Revised 09/01/2018
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#3 - Streamlines ENERGY STAR Program Requirements

Streamlines ENERGY STAR program requirements

- An energy rating completed with certain features locked in:
  - Target score
  - Grade I insulation
  - Grade I or II HVAC grading
  - Minimum insulation levels, window/door ratings, duct leakage
- Plus:
  1. Bedroom pressure-balancing for comfort
  2. Reduced thermal bridging for comfort
  3. Air sealing details for efficiency and comfort
  4. Indoor air quality features for health
  5. Water management system features for durability, required by code

Status Update On HVAC Grading Standard

Status Update

1. **Standard 310: HVAC Grading Standard**
   - **What it does:** Defines how the Rater completes the design review, field tests, and designates the grade.
   - **Status:**
     - 1st comment period has concluded
     - 2nd comment period should commence in November
     - Aiming to finalize in Q1 2020

Status Update

2. **Standard 301: Energy Ratings Update (Non-calcs):**
   - **What it does:** Integrates Std. 310 into the overall rating process; updates definitions, minimum rated features, and on-site inspection protocols.
   - **Status:**
     - Submitted in September
     - Aiming to finalize in Q1 2020

Status Update

3. **Std. 310 HVAC Design Report Templates:**
   - **What it does:** Incorporates Std. 310 design documentation requirements into Wrightsoft and RHVAC templates.
   - **Status:**
     - Discussions have started
     - Aiming to finalize in Q2 2020

Status Update

4. **RESNET Rater Training:**
   – **What it does:** Trains raters on new requirements in Std. 310, prior to use.
   – **Status:**
     - Development has started
     - Aiming to finalize in Q2 2020

Status Update

5. **Calculations Update:**
   – **What it does:** Updates standards and software to provide credit for properly installed HVAC systems.
   – **Status:**
     - In process – discussing with RESNET the value of rewarding properly installed HVAC systems in both ERI ratings and HERS ratings.
     - More to come..

Q & A

ENERGY STAR Certified Homes

Web:

Home: www.energystar.gov/newhomespartners

Technical: www.energystar.gov/newhomesrequirements

MESA: www.energystar.gov/mesa

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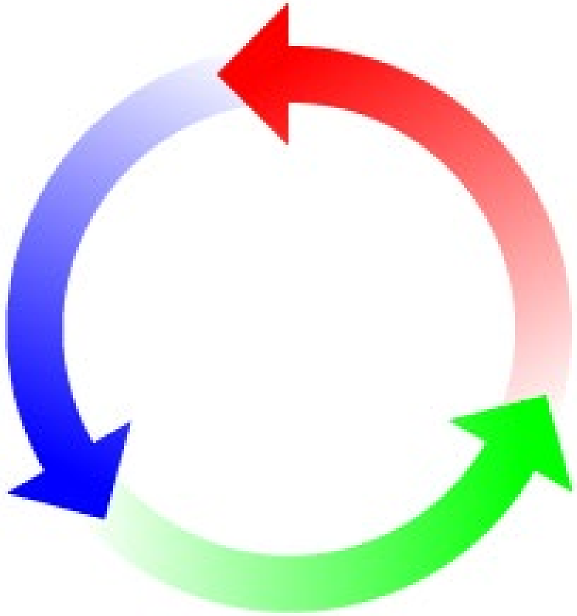
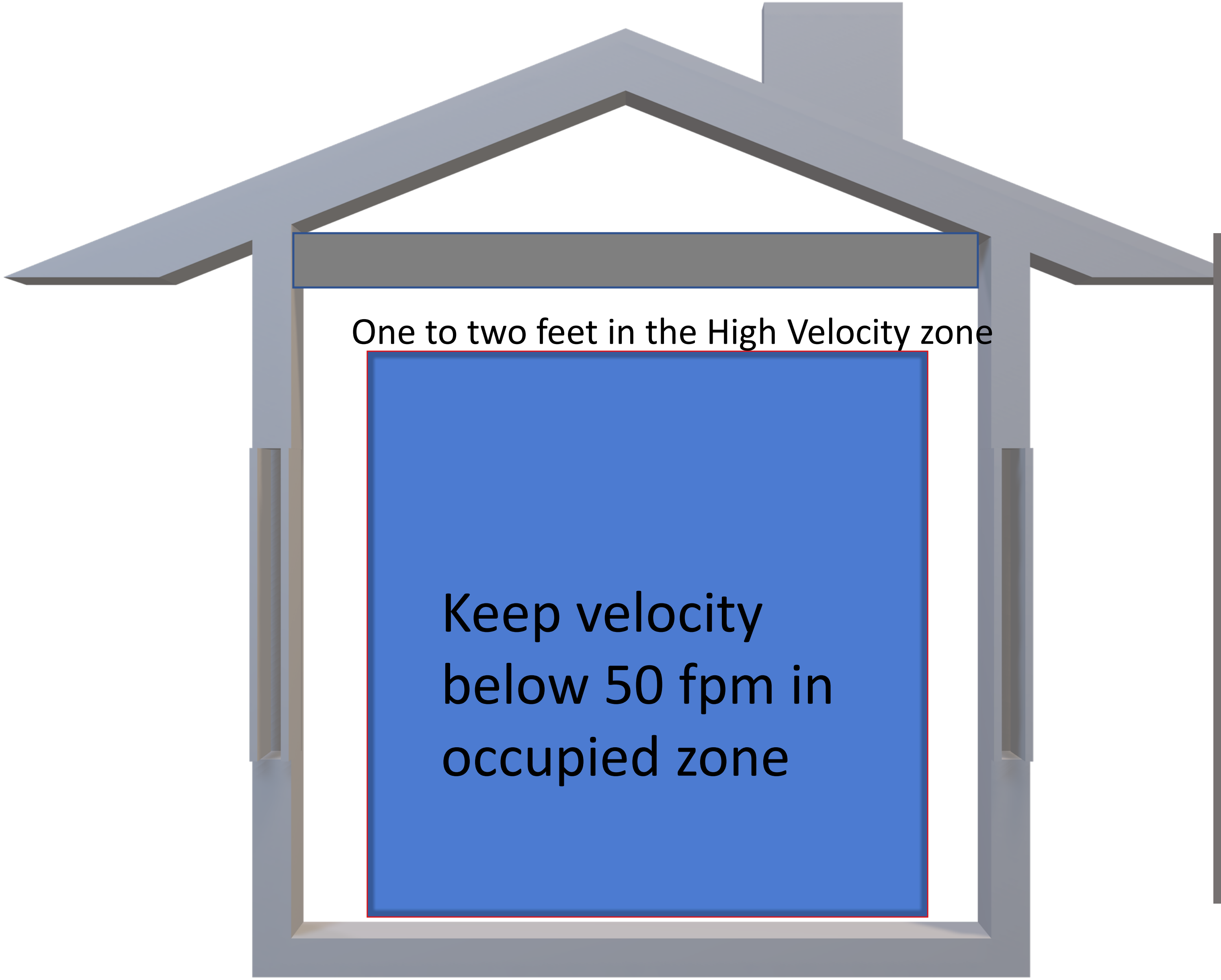


Where The Air Goes In, And Where The Comes Out: The importance of selecting Grilles Registers and Diffusers



Two Zones:

The Occupied Zone:

The High Velocity Zone

Buoyancy: Warm air wants to rise,cold air wants to fall.

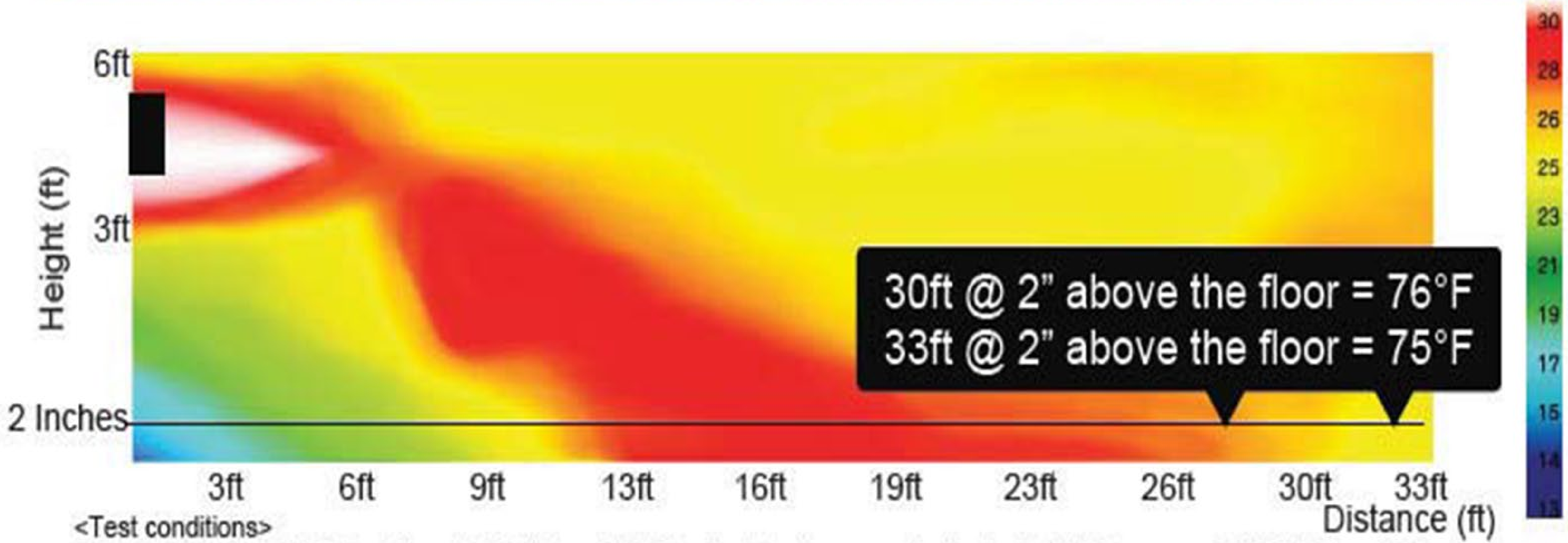
Heating Dominated: Floor

Cooling Dominated: Ceiling

Real World Dominated: Cost

The Perfect Diffuser?

Effective Air Throw & Temperature Distribution for Larger Rooms



<Test conditions>

Outdoor temp.: 35°F R/C setting: 73°F, "Powerful" 30 min. later the operation is started. Test room : 350ft² Test model :

Its Even More Important in A Low Load House

IBACOS

WHAT'S IT ALL MEAN?

- *Lower loads, lower airflow (cfm) per room*
- *Lower airflow = less air available to mix for the same volume room*
- *Same size house, same length ducts, lower airflow, duct tightness critical*
- *Long runs, less airflow, takes time to heat up duct mass, lower outlet temperatures at long runs on short cycles*
- *Register selection is critical*

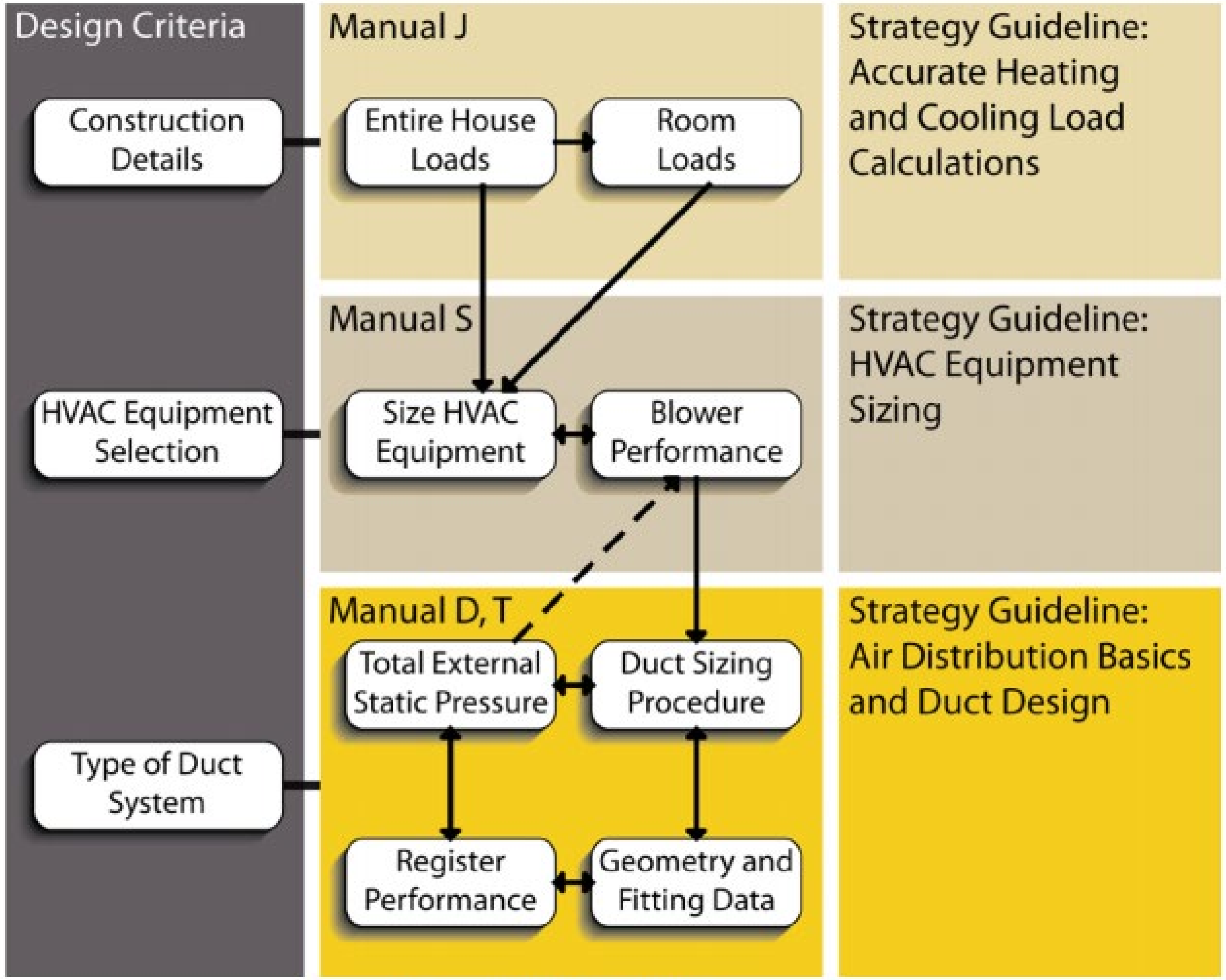
Courtesy of Ibacos

We Used To Be The Boss of Air!

	System size sf/ton	Air flow cfm/sf	Air exchange rate ACH nat
Historic “Rule of Thumb”	**400**	**1.0**	**0.5 - 0.75**
Energy Star – Cold Climate	**1107**	**0.35**	**0.31**
Energy Star – Mixed Humid Climate	**1124**	**0.34**	**0.34**
40% BA – Cold Climate	**1476**	**0.26**	**0.10**
40% BA – Mixed Humid Climate	**1311**	**0.27**	**0.19**

Courtesy of Ibacos

Eating Your ACCA Vegetables



Before We Get Started:

Before you select and place a GRD you must:
1: Know the heat lost/gain per room
2: Know the cfm per room
3: Size the duct system correctly
4: Install the duct work correctly
5: Eat your vegetables and floss daily

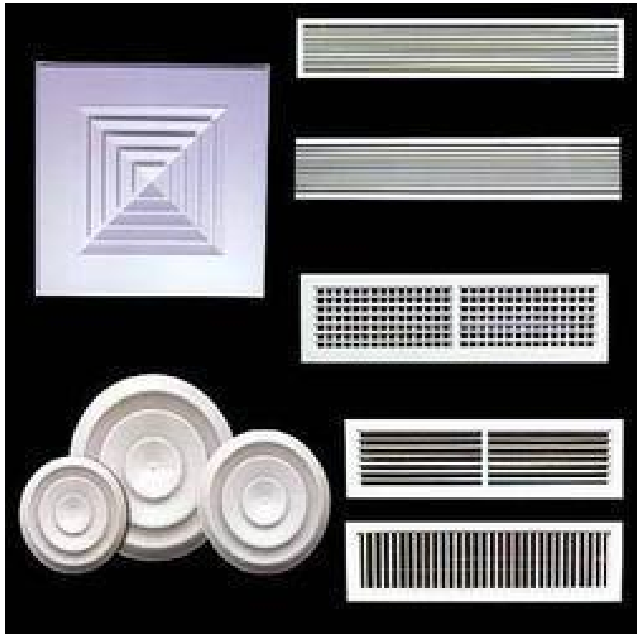
A Few Definitions

Grille: A louvered covering for an opening through which air passes.

Register: A grille which is equipped with a damper or control valve, and which directs air in a nonspreading jet.

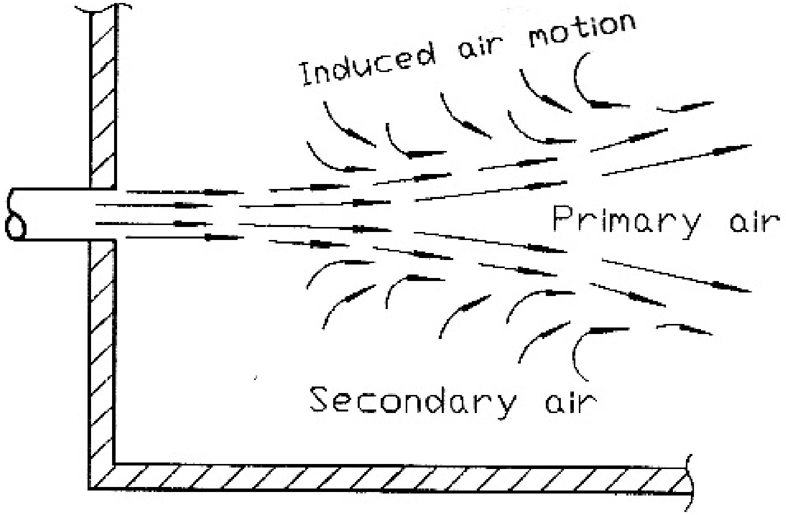
Diffuser An outlet discharging supply air in a spreading pattern.

Stratification Boundary The boundary between room air currents



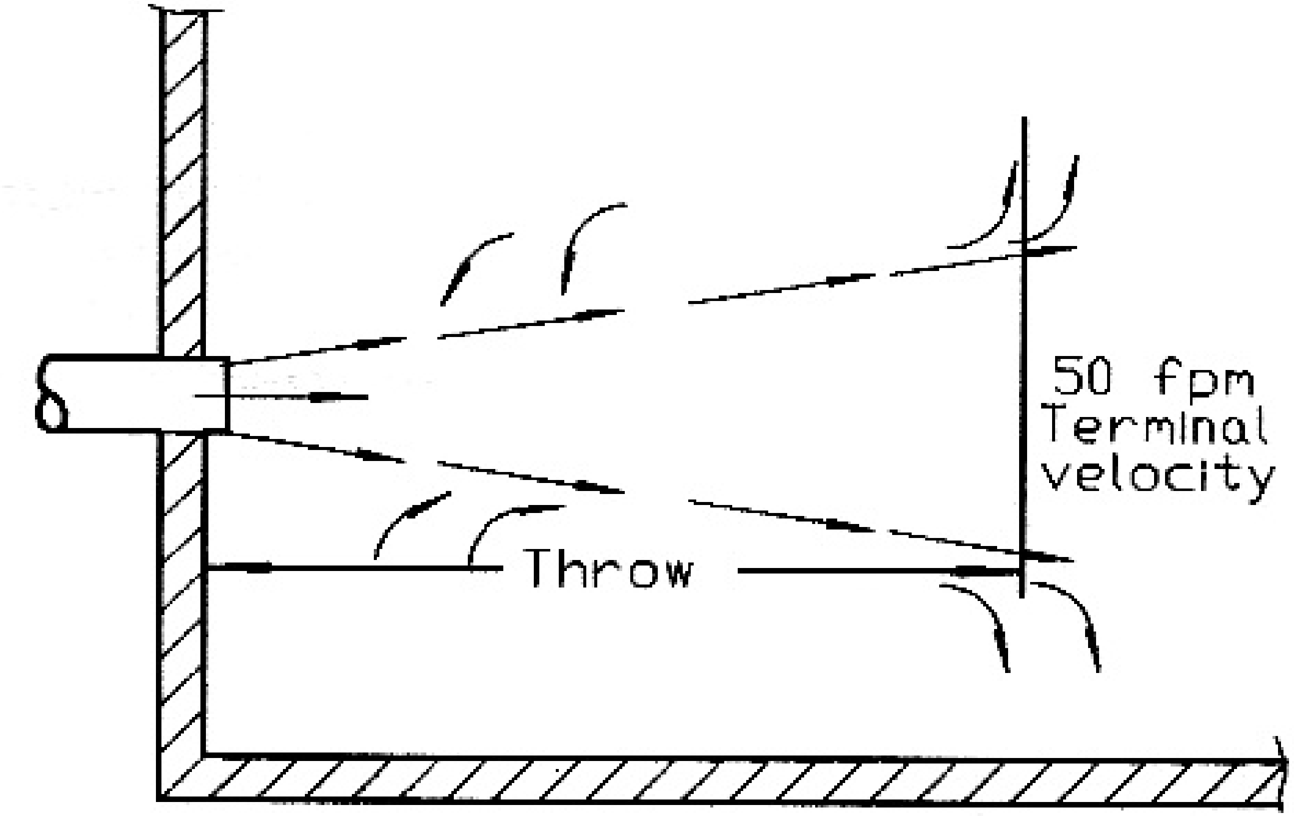
Air Mixing in a Zone. It's all about entrainment

- Primary air induces or set in motion the air surrounding it.
- Secondary air is 10 to 20 times the volume of the primary air.
- Hence 80 cfm of primary air sets 800 to 1600 cfm of secondary air into motion.



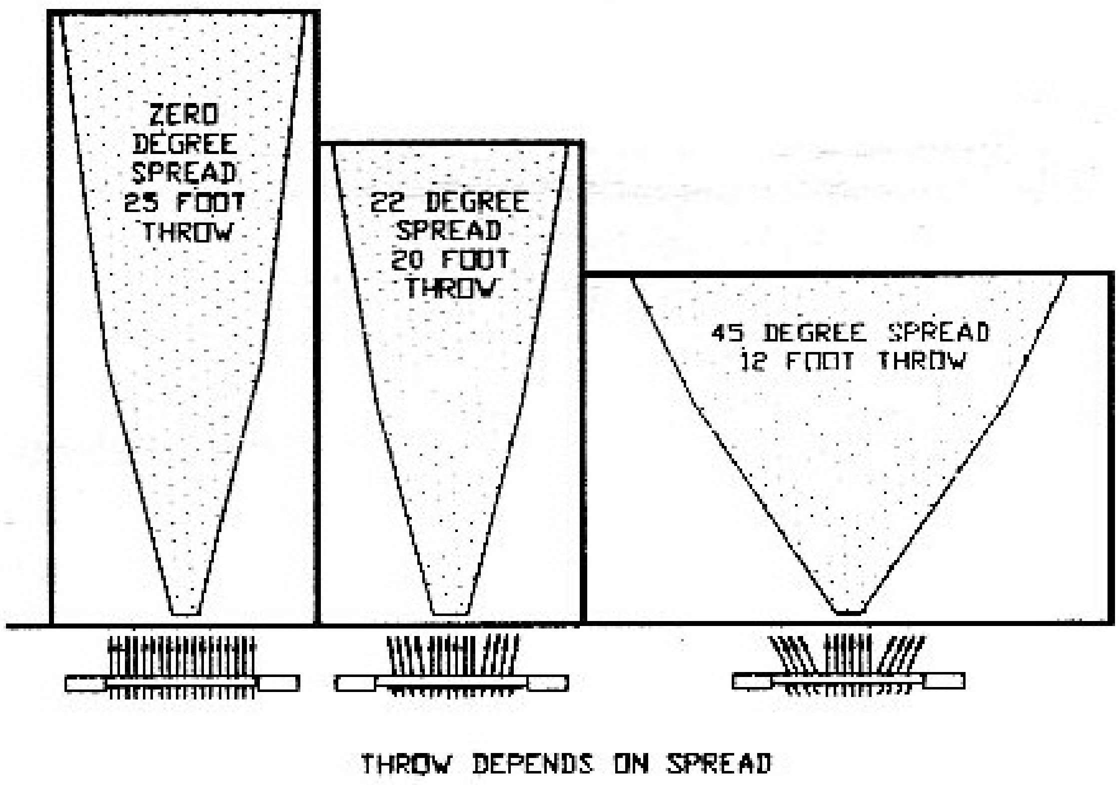
Register Throw

- Throw is the distance the air travels before it reaches some specific value (usually 50 feet per minute).

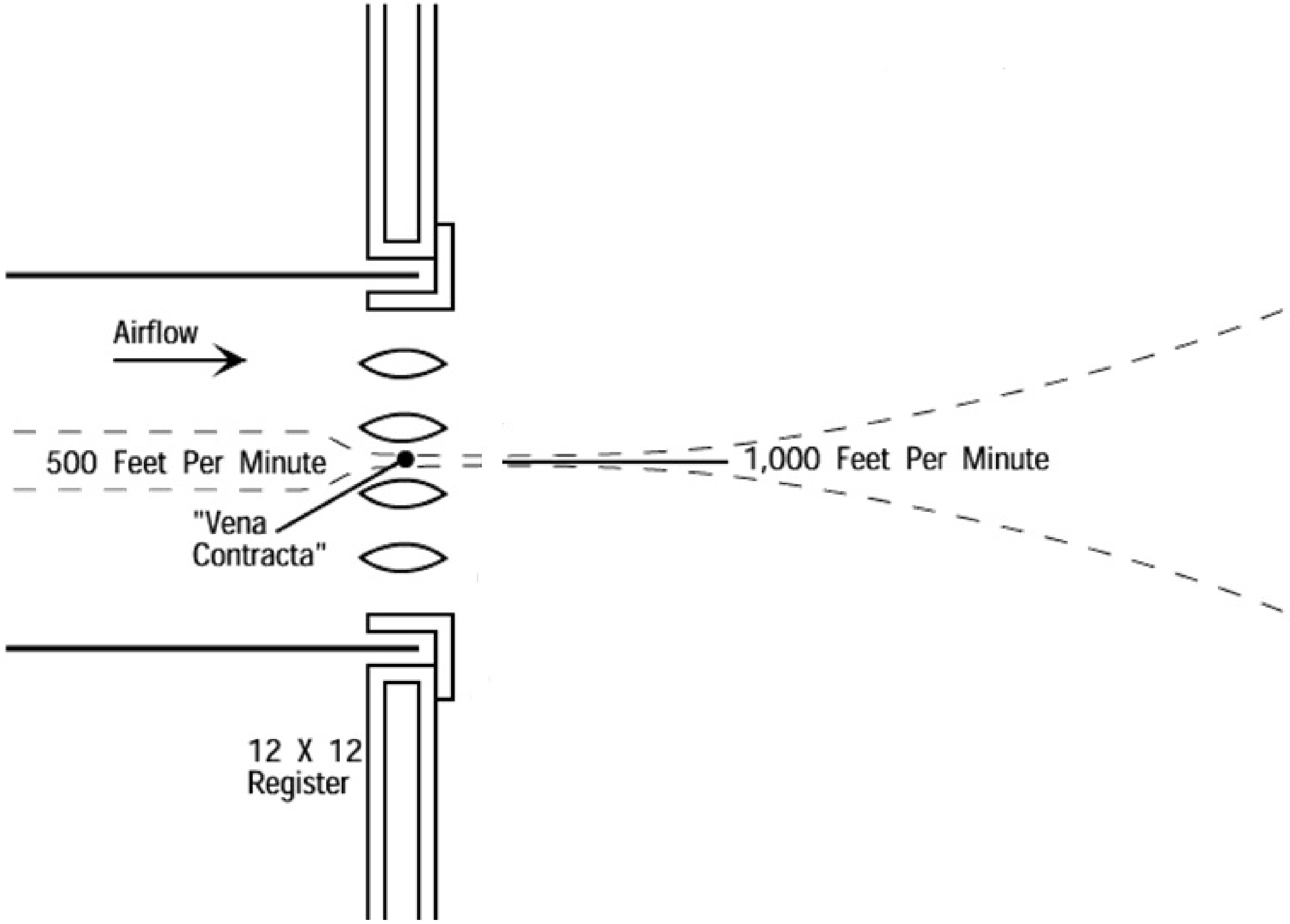


Register Spread

- Spread refers to how wide the jet of primary becomes
- Spread decreases and throw increases

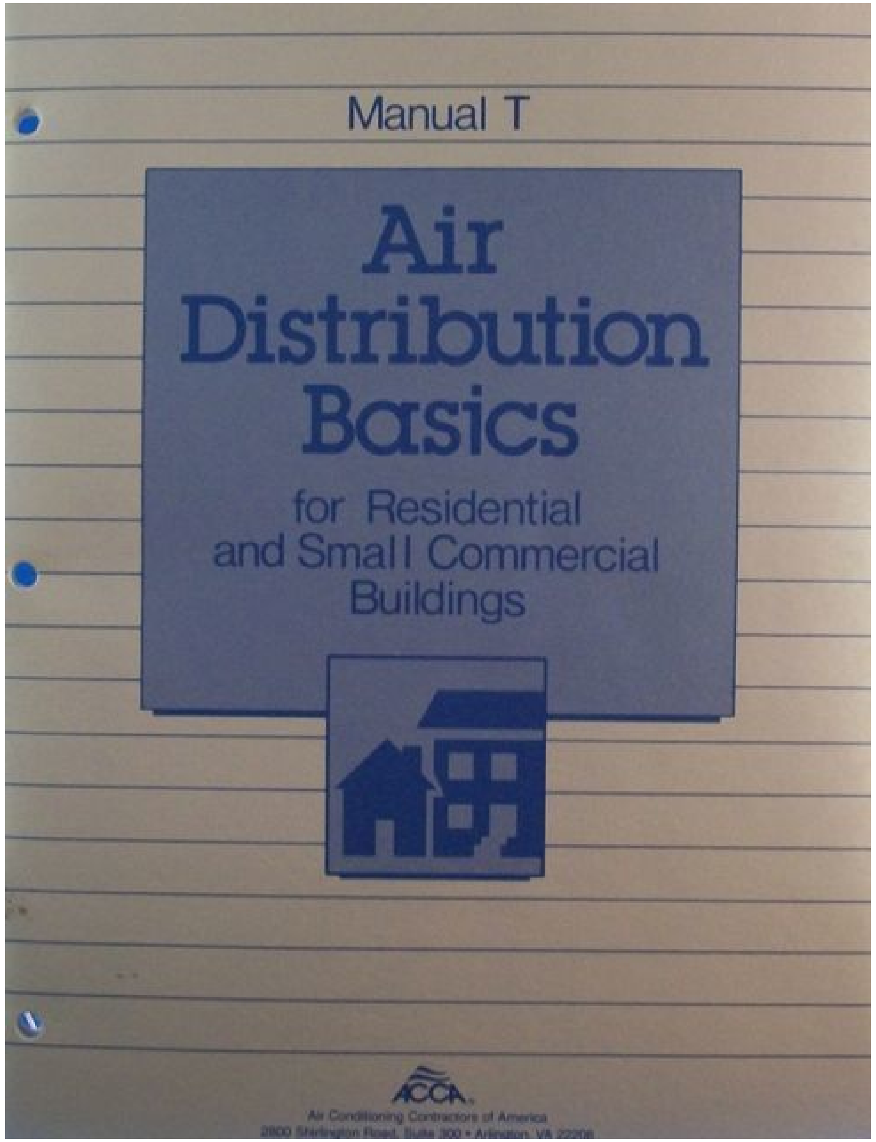


Why Not Just Have Holes In The Ceiling



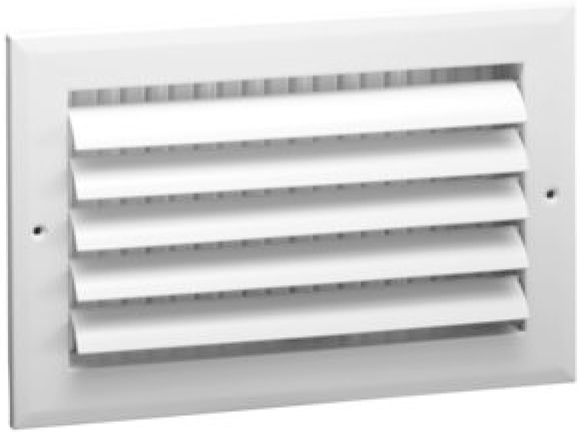
Grille and Register Selection

- **ACCA's Manual "T" gives selection criteria**
  - **Good selection:**
    - Provides good mixing
    - Prevents "cold drafts"
    - Reduces noise
    - Increases aesthetic appeal
    - Good registers can increase cost $20 to $40 per grille/register.



Think High Side Wall Delivery

- Helps To Make the Duct System Compact
- Keeps higher velocity air out of the comfort zone
- Performs well in heating and cooling
- Uses outside wall and window to “drop” the air



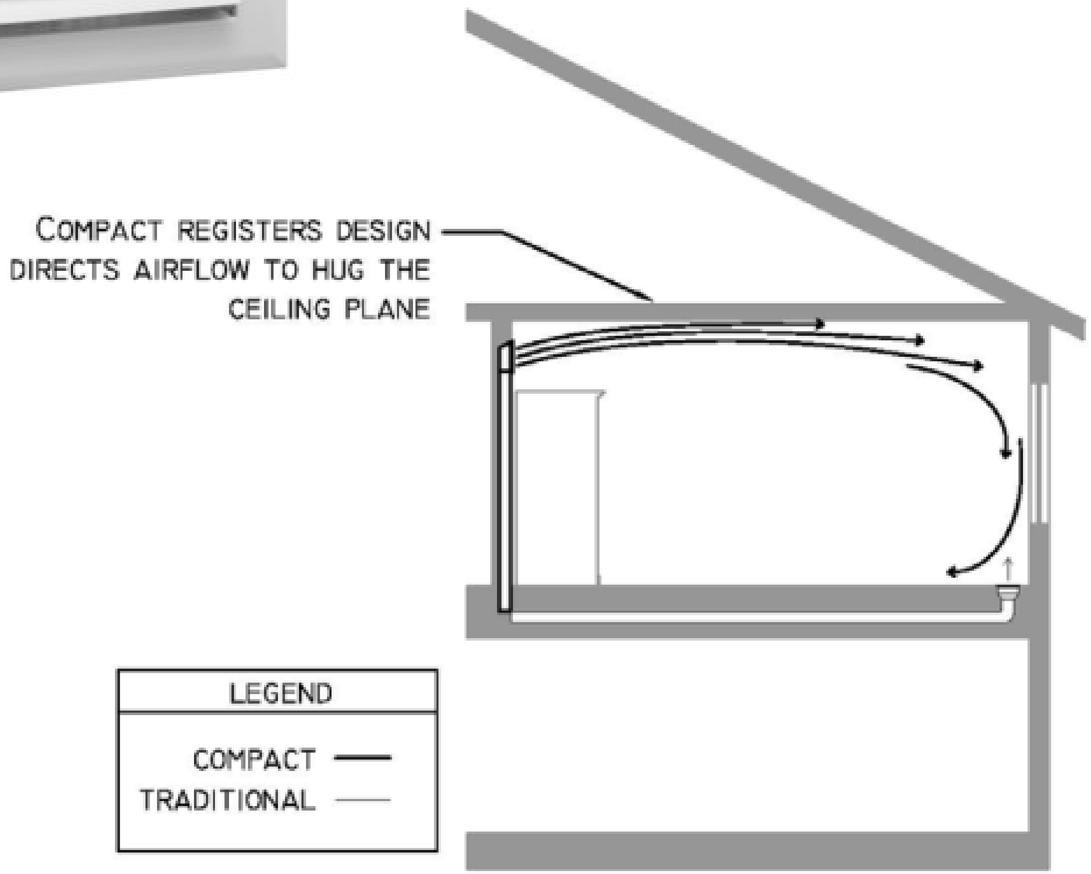


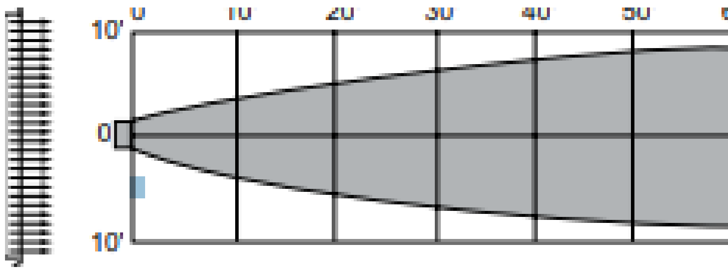
Figure 4. High sidewall versus floor register—section view

What's the Best High Side Wall Register size for 150CFM In a room that’s 15ft long

Face Velocity		300	400	500	600	700	800	900	1000	1100	1200
Pressure Loss		.006	.010	.016	.022	.031	.040	.050	.062	.075	.090
8 x 4	CFM	45	60	80	95	110	125	140	155	170	185
Ak .156	Throw	5.0	6.5	8.5	10.0	12.0	13.0	15.0	16.0	18.0	19.0
10 x 4	CFM	60	80	100	120	140	160	180	200	220	24(
Ak .198	Throw	6.0	7.5	9.5	12.0	13.0	15.0	17.0	19.0	20.0	22.(
12 x 4	CFM	70	95	120	145	170	190	215	240	265	29(
Ak .240	Throw	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	25.(
10 x 6	CFM	95	125	155	190	220	250	280	315	345	37
Ak .313	Throw	7.0	9.0	12.0	14.0	16.0	19.0	21.0	23.0	26.0	28.(
12 x 6	CFM	115	150	190	225	265	305	340	380	415	45
Ak .379	Throw	8.0	10.0	13.0	15.0	18.0	21.0	23.0	26.0	28.0	31.(
10 x 8	CFM	130	170	215	255	300	340	385	425	470	51(
Ak .425	Throw	8.0	11.0	14.0	16.0	19.0	21.0	24.0	27.0	30.0	32.(
14 x 6	CFM	135	180	225	270	310	355	400	445	490	54
Ak .446	Throw	8.0	11.0	14.0	17.0	19.0	22.0	25.0	28.0	30.0	33.(
12 x 8	CFM	160	200	265	320	370	425	475	530	585	635
Ak .530	Throw	9.0	11.0	15.0	18.0	21.0	24.0	27.0	30.0	33.0	36.0
14 x 8	CFM	185	250	310	370	435	495	560	620	680	745
Ak .620	Throw	10.0	13.0	16.0	20.0	23.0	26.0	30.0	33.0	36.0	39.0
For sizes not listed or sizing tips see page 35											

Terminal Velocity of 75 FPM

A618 Adjustable Fin Register
(Page 17)
Deflection A



Pick a ceiling register for 80 CFM
80 CFM

Face Velocity		300	400	500	600	700	800	900	1000
Pressure Loss		.006	.010	.016	.022	.031	.040	.050	.062
8 x 6	CFM	40	55	70	90	100	110	125	140
Ak .140	Throw	5.0	6.0	8.0	9.0	11.0	12.0	14.0	15.0
10 x 6	CFM	55	80	95	110	130	150	165	185
Ak .185	Throw	5.0	7.0	10.0	11.0	13.0	14.0	16.0	18.0
12 x 6	CFM	70	90	115	135	160	180	205	225
Ak .225	Throw	6.0	8.0	12.0	12.0	14.0	16.0	18.0	20.0
14 x 6	CFM	85	115	145	175	205	230	260	290
Ak .290	Throw	7.0	9.0	16.0	14.0	17.0	19.0	21.0	24.0
16 x 6	CFM	100	130	165	200	230	265	295	330
Ak .330	Throw	8.0	10.0	18.0	15.0	18.0	20.0	23.0	25.0
18 x 6	CFM	115	155	195	235	275	310	350	390
Ak .390	Throw	8.0	11.0	21.0	17.0	20.0	22.0	25.0	28.0
20 x 6	CFM	130	175	220	265	310	360	395	440
Ak .440	Throw	5.0	12.0	24.0	18.0	21.0	24.0	27.0	30.0

Terminal Velocity of 75 FPM

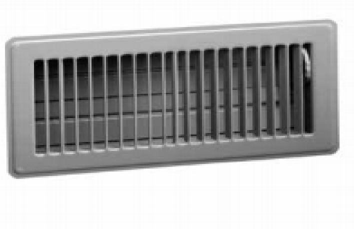
A618MS/A618OB Register

- Aluminum face/fin construction
- Adjustable straight fins provides individual deflection control
- Stamped face margins eliminate mitered corners and rough edge
- Galvanized multi-shutter valve or

Face Velocity		300	400	500	600	700	800	900	1000
8 x 4	CFM	28	38	47	57	66	76	85	95
Ak .095	Ps	.02	.02	.02	.03	.04	.05	.06	.07
	Throw	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
10 x 4	CFM	35	47	59	70	82	94	105	117
Ak .117	Ps	.01	.01	.02	.02	.03	.04	.05	.06
	Throw	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
10 x 6	CFM	58	77	97	116	135	154	174	193
Ak .193	Ps	.01	.01	.02	.02	.03	.04	.05	.06
	Throw	1.5	2.0	2.5	3.0	3.5	4.5	5.0	5.5
12 x 6	CFM	71	95	119	143	167	190	214	238
Ak .238	Ps	.01	.01	.01	.02	.03	.04	.05	.06
	Throw	5.5	7.0	9.0	10.5	12.5	14.0	16.0	17.5
14 x 6	CFM	87	116	145	174	204	233	262	291
Ak .291	Ps	.01	.01	.02	.02	.03	.04	.05	.06
	Throw	NA	NA	NA	NA	NA	NA	NA	NA
14 x 8	CFM	119	158	198	237	277	316	356	395
Ak .395	Ps	.01	.01.	.01	.02	.03	.04	.05	.06
	Throw	NA	NA	NA	NA	NA	NA	NA	NA

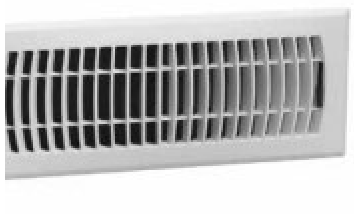
Terminal Velocity of 75 FPM

NA = Not Available



421 Floor Diffuser

- All-steel construction
- Multi-angle fin setting
- Rolled fin for strength and safety
- Welded construction
- Foot-operated dial control
- Heavy-gauge stamped face
- Golden Sand or Bright White enamel finish



Rezzin Plastic Floor Diffuser

- Solid ABS construction for floor use
- Multi-angled fins for fan pattern of air distribution
- Foot-operated, opposed-blade damper
- Bright White or Brown finish

420/421 Floor Diffuser (Page 7)

Face Velocity		300	400	500	600	700	800	900	1000
Pressure Loss		.006	.010	.016	.022	.031	.040	.050	.062
2 x 10 Ak .085	CFM		35	45	50	60	70	75	85
	Spread		3.0	5.0	5.0	6.0	7.0	8.0	9.0
	Throw		4.0	4.5	6.0	7.0	8.0	9.0	10.0
2 x 12 Ak .100	CFM	30	40	50	60	70	80	90	100
	Spread	3.0	4.0	4.5	5.5	6.5	7.0	8.0	9.0
	Throw	3.5	4.5	5.5	7.0	8.0	9.0	10.0	11.0
2 x 14 Ak .115	CFM	35	45	60	70	80	90	105	115
	Spread	3.5	4.0	5.0	7.0	7.0	8.0	9.0	10.0
	Throw	3.5	4.5	6.0	8.0	8.0	9.5	10.5	12.0
4 x 8 Ak .130	CFM	40	50	65	80	90	105	115	130
	Spread	3.0	4.0	5.0	6.5	7.5	8.5	9.5	11.0
	Throw	4.0	4.5	6.0	7.5	8.5	10.0	11.0	13.0
4 x 10 Ak .170	CFM	50	70	85	100	120	135	155	170
	Spread	4.5	5.0	6.5	7.5	9.0	10.0	11.5	13.0
	Throw	4.0	6.0	8.0	10.0	11.0	12.5	14.0	15.5

Rezzin Floor Diffuser (Page 8)

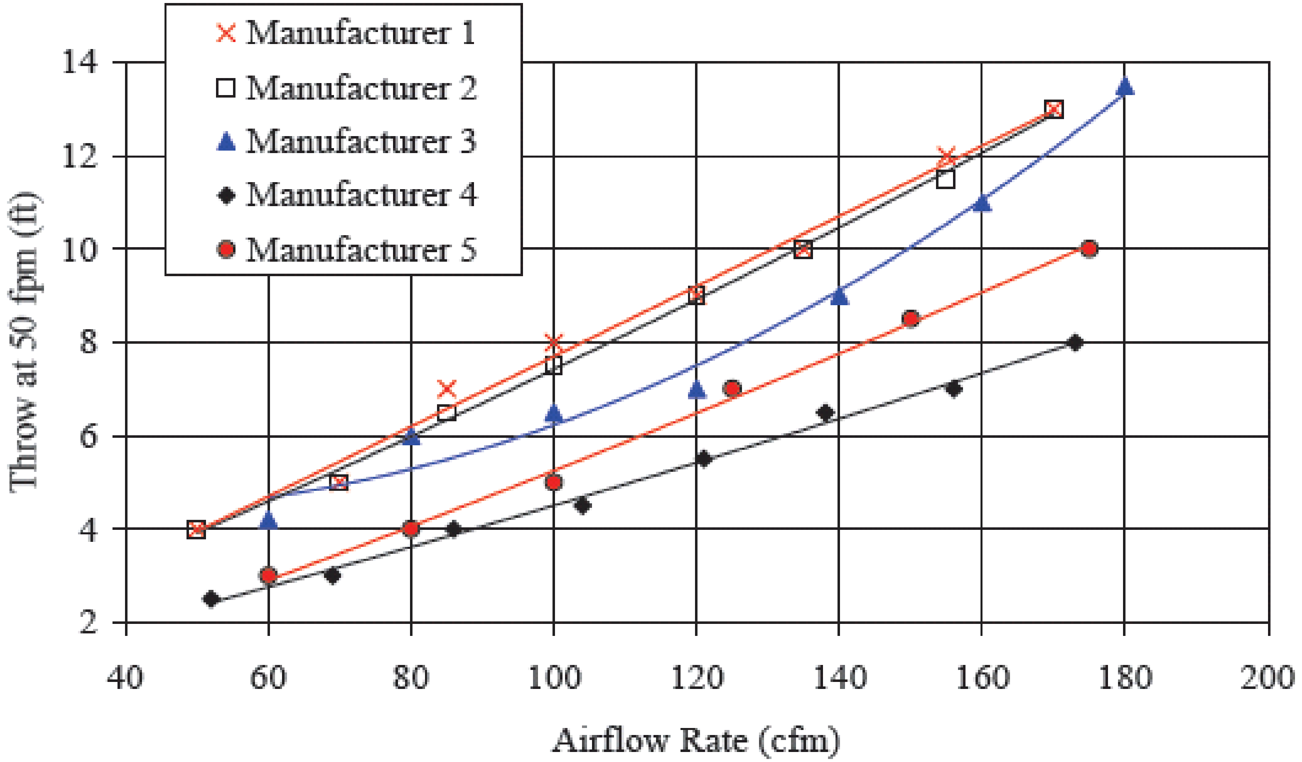
Face Velocity		300	400	500	600	700	800	900	1000
2 x 12 Ak .084	CFM	25	34	42	50	59	67	76	84
	Ps	.01	.02	.03	.05	.06	.08	.10	.12
	Throw	2.0	2.5	3.5	4.0	4.5	5.5	6.0	6.5
	Spread	1.5	2.0	2.5	3.0	3.0	3.5	4.0	4.5
4 x 10 Ak .141	CFM	42	56	71	85	99	113	127	141
	Ps	.02	.02	.03	.04	.06	.07	.09	.11
	Throw	2.0	2.5	3.0	3.5	4.5	5.0	5.5	6.0
	Spread	0.5	1.5	2.5	3.0	4.0	5.0	5.5	6.5
4 x 12 Ak .157	CFM	47	63	79	94	110	126	141	157
	Ps	.02	.03	.04	.05	.07	.09	.11	.13
	Throw	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
	Spread	0.5	1.5	2.5	4.0	5.0	6.0	7.0	8.0

Terminal Velocity of 50 FPM

Performance of Various Supply Registers

Register Selection Criteria

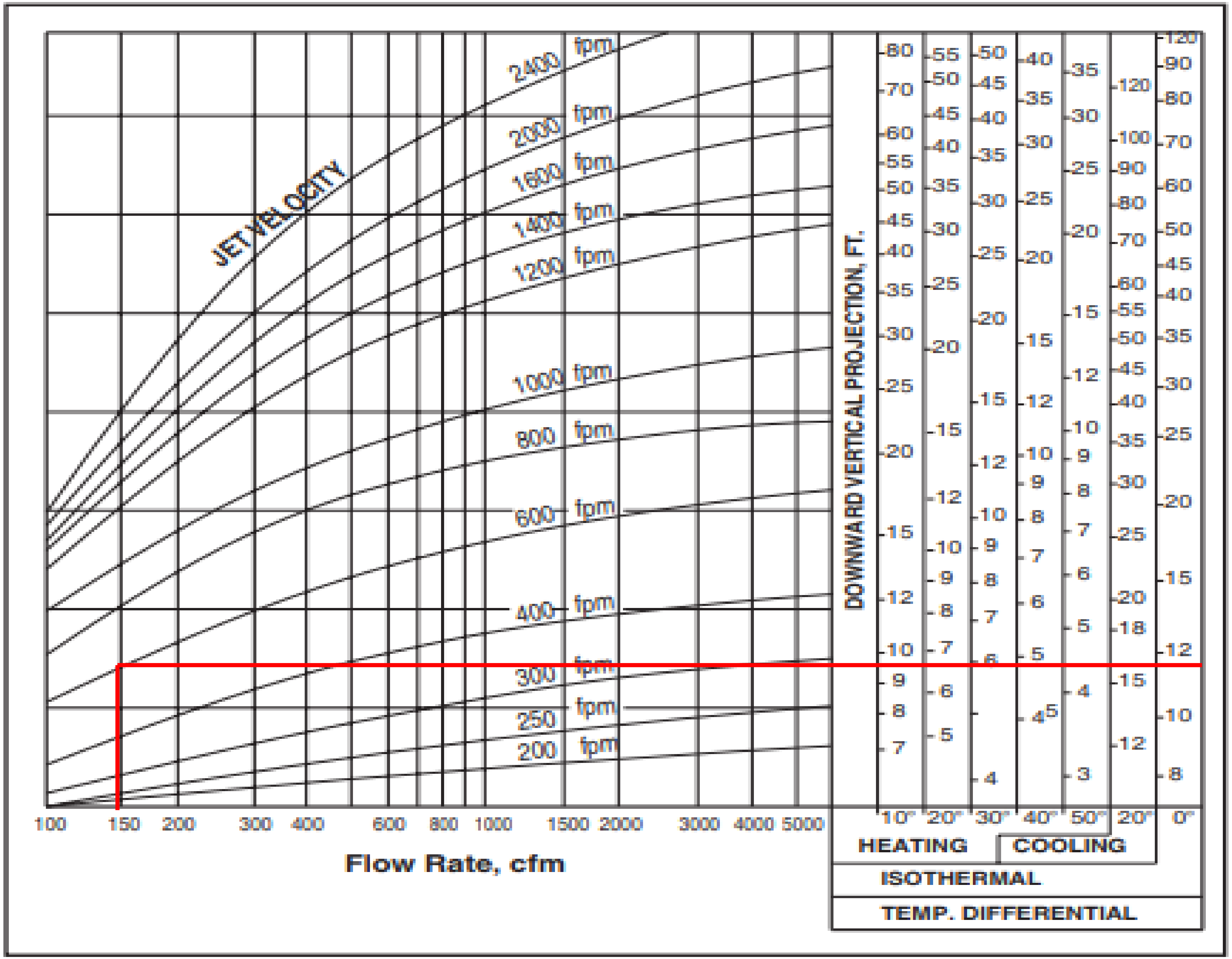
- *Throw*
- *Pressure Drop*
- *Noise*



Floor Register Performance (10x4)

Courtesy of Ibacos

Isothermal Correction Or How to Cut the downward throw in half



One More Vegetable: Entry Conditions Matter

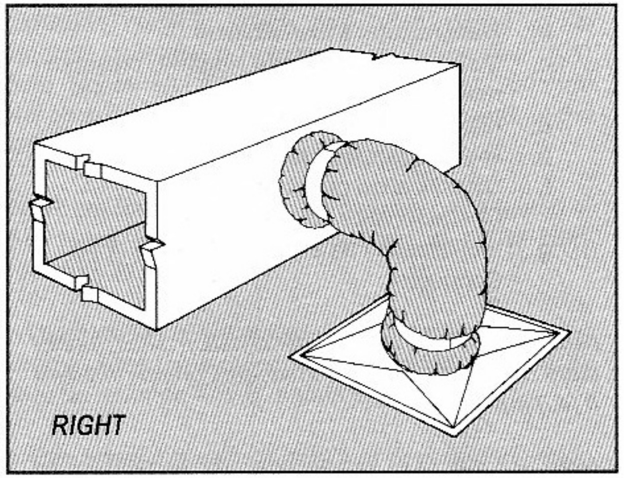


Figure 6

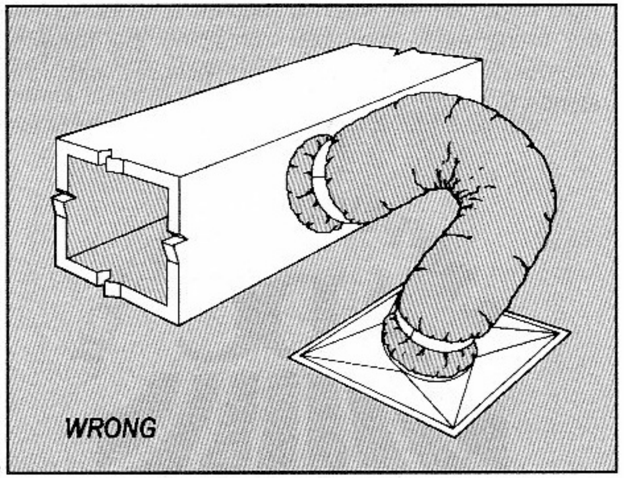


Figure 7

Return: Just a hole for the air to get back to the air handler

- They have very little impact on air distribution patterns
- Bigger is better
  - Better filtration
  - Lower Noise
  - More static (muscle) for the supply side

Sizing Returns

- 400 – 500m fpm max
- 300 max for filter grilles

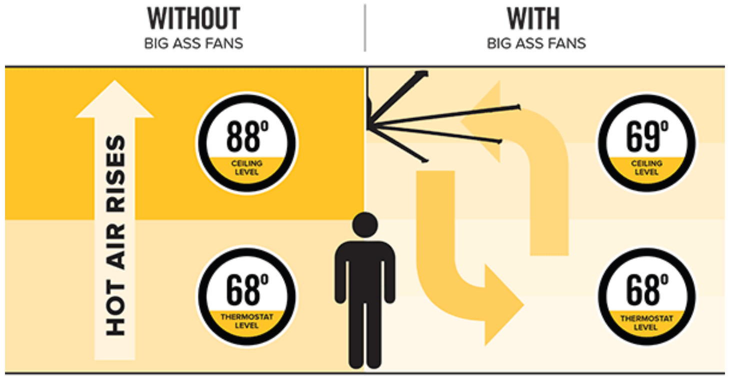
- On stamp faced grilles, keep it below 400 fpm for noise purposes

- Rule of thumb 2 cm per filter size

Filter Size		Area (in^2)	Ton (cfm)	Filter Size		Area (in^2)	To
12	12	144	n/a	20	20	400	2
12	20	240	1 (400)	20	25	500	2.5
12	24	288	1.5 (600)	20	30	600	3
12	30	360	1.5 (600)	20	36	720	3
14	14	196	1 (400)	24	24	576	3
14	20	280	1.5 (600)	24	30	720	3
14	24	336	1.5 (600)	24	36	864	4
14	30	420	2 (800)	25	25	625	3
16	20	320	1.5 (600)	30	30	900	4
16	24	384	2 (800)	30	36	1080	5

A Few Guidelines

1. Keep pressure drop below .03 IWC
2. KEEP NC below 35
3. Keep FPM below 700 on supply side
4. Don’t inject air into the comfort zone <50fpm
5. Make big returns



What They Do in the South:

Zen Like Question For The Day

- *How should you design ducts and select registers for a variable speed system?*

- A: Don’t worry about it
- B: At the top speed
- C: At the speed it will be used at the most