IBACOS

Best Practices in Home Building ™

Residential Air Distribution for High Performance Homes

The High Performance Challenge

Central system, Air based space conditioning systems are being "designed" at the boundaries of their ability to perform.

At 400 CFM per ton, older homes (the 1970's) required about 1 ton per 400 to 500 square feet

Homes designed to "better than code" require just 1/2 ton for the same 400 square feet

Homes we are designing to meet the Zero Energy Goal are between 1500 and 2000 sf/ton

System Characteristics

	System size sf/ton	Air flow cfm/sf	Air exchange rate ACH
Historic Standard	400	1 cool	7.5
Base House, Austin TX	480	.82 cool	5.5
Lab C, Austin TX (HP)	580	.68 cool .74 heat	4.9
YPG House, Yuma AZ (HP)	580	.63 cool .63 heat	3.4
Civano, Tuscon AZ	600-900	---	---
Lab House E, Pittsburgh PA	1000	.36 cool	2.4
IBACOS Demonstration Home	1500	.26 cool	1.6

Exploring Solutions

This talk will focus on modifications to current air based distribution system to increase the comfort potential and utilize systems based on the 400 cfm per ton energy balance of current DX systems

In the future we will need to heat with cooler air

we will need to cool with warmer air

we will need to not use central systems

we will need to have more thermostats

WE WILL NEED TO THINK DIFERENTLY

Parts and Pieces
of this talk

- NREL Modeling showing register engineering discovery
- IBACOS study of high performance home with zoned air based heating system
- Register and room mixing characterization study
- Guidance for engineering a high performance space conditioning system
- A quiet request for commissioning

Low velocity mixing study

Evaluation of Design Requirements for Mixing of Room Air Using Low Velocity, Low Delta T Ceiling Jets

Figure 2. Room Dimensions Used in Study

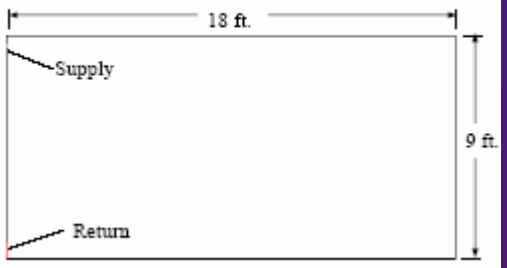
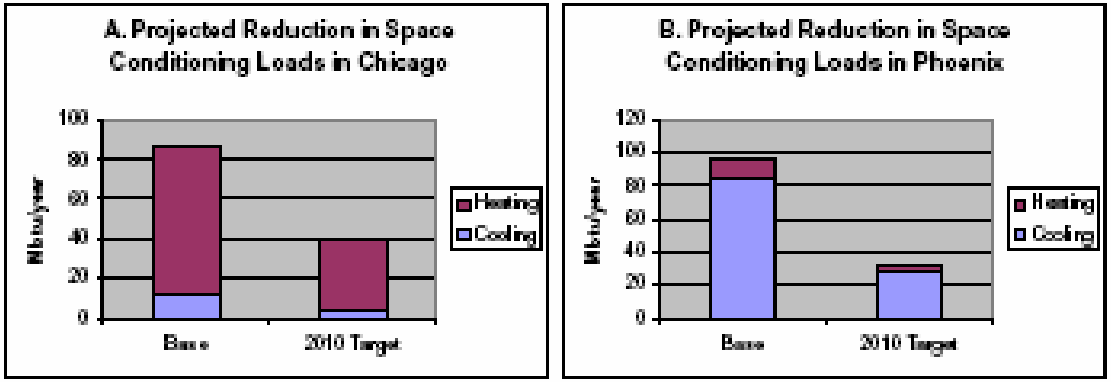


Figure 1. Trends in Space Conditioning Loads in Building America Houses



Ren Anderson
Keith Gawlik
National Renewable Energy Laboratory

Progress Report
March 23, 2005

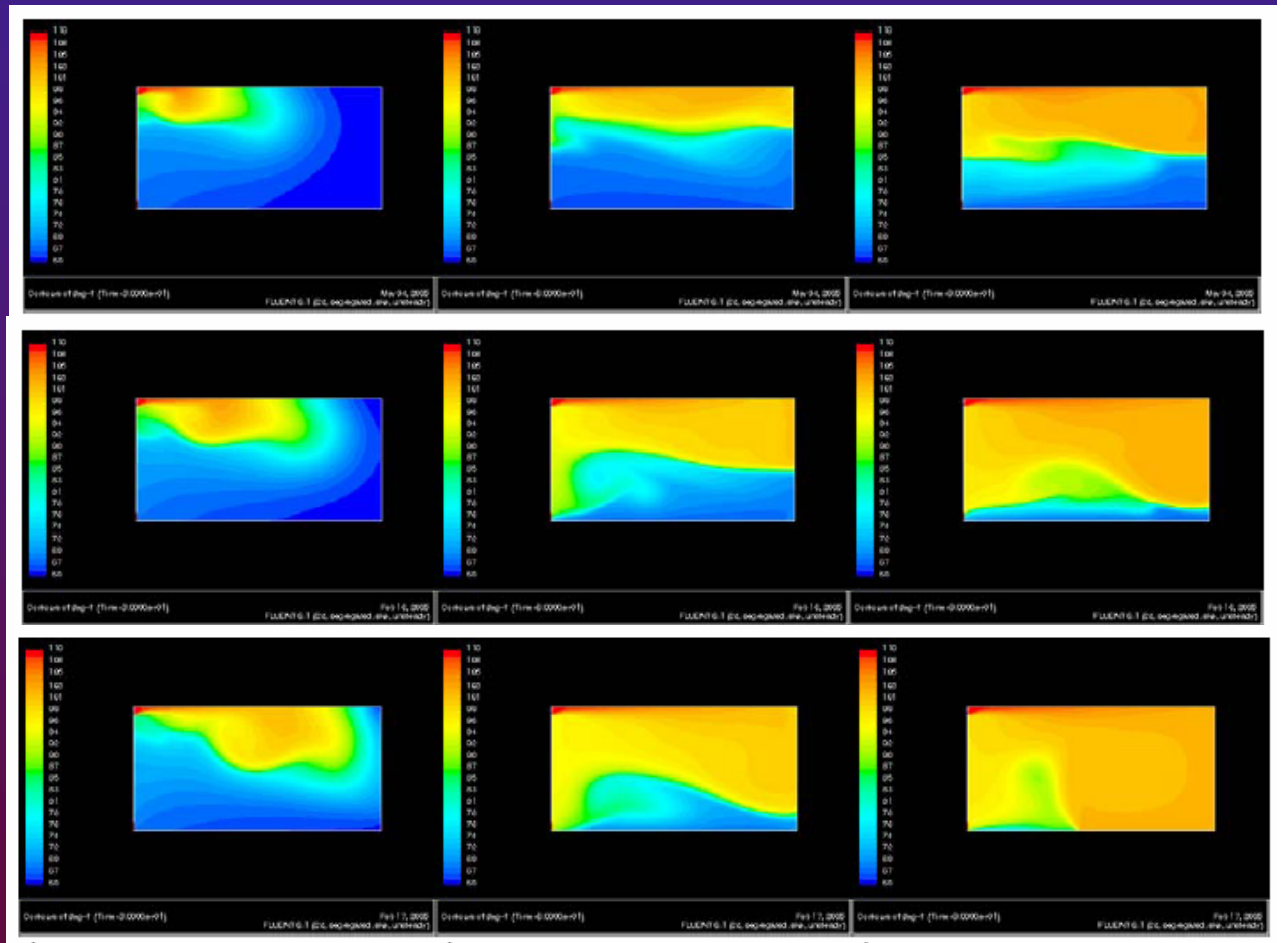
110 F supply air temperature

Supply air Velocity

394 f/m

591 f/m

787 f/m



time = 30 sec time = 60 sec time = 90 sec

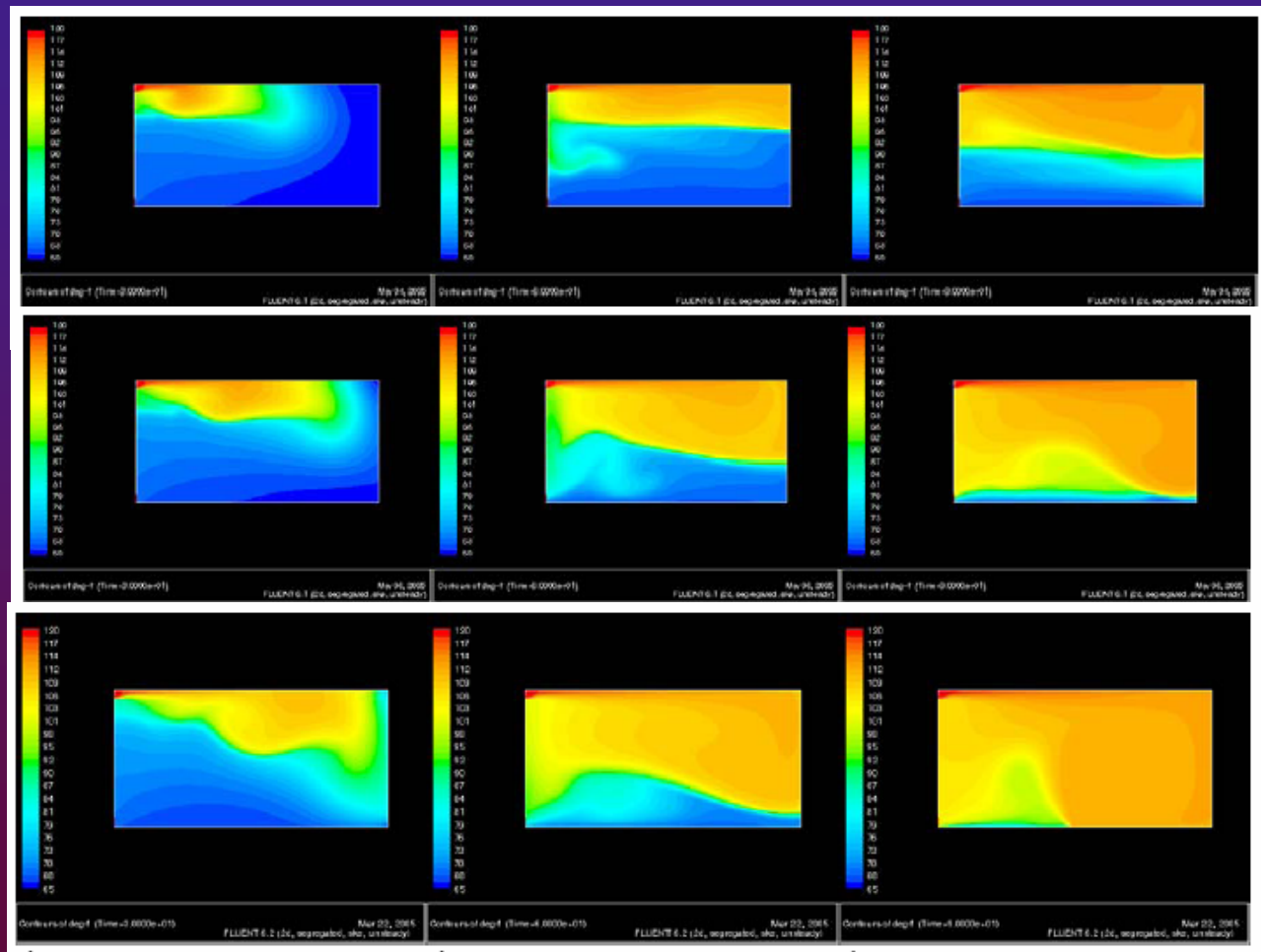
130 F supply air temperature

Supply air Velocity

394 f/m

591 f/m

787 f/m



time = 30 sec time = 60 sec time = 90 sec

140 F supply air temperature

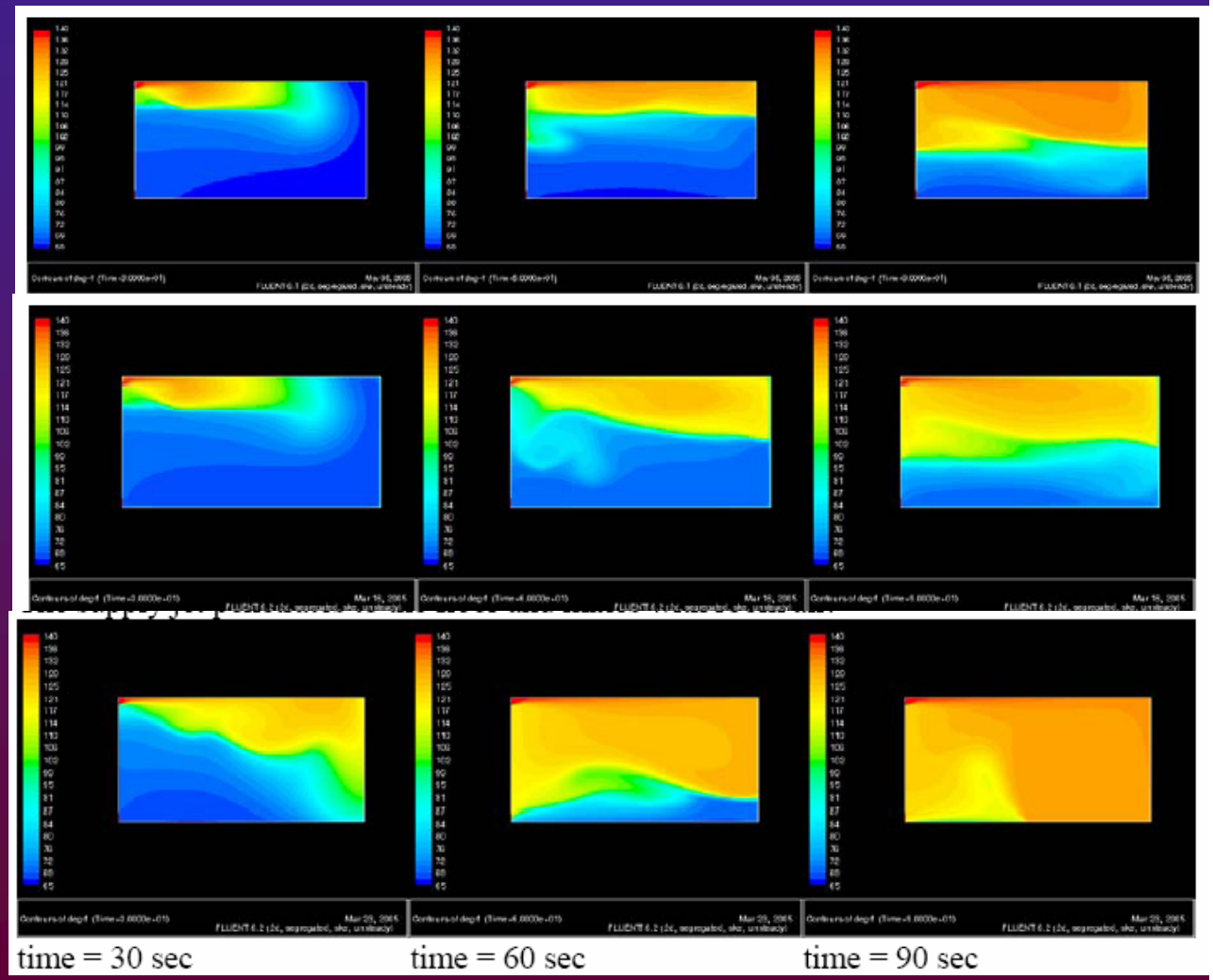
Supply air Velocity

394 f/m

394 f/m

Radiation Enabled
Wall heat loss
allowed

787 f/m



time = 30 sec time = 60 sec time = 90 sec

Design Implications

Supply

65	dT	T-sec
110	45	90
120	55	74
130	65	62
140	75	54

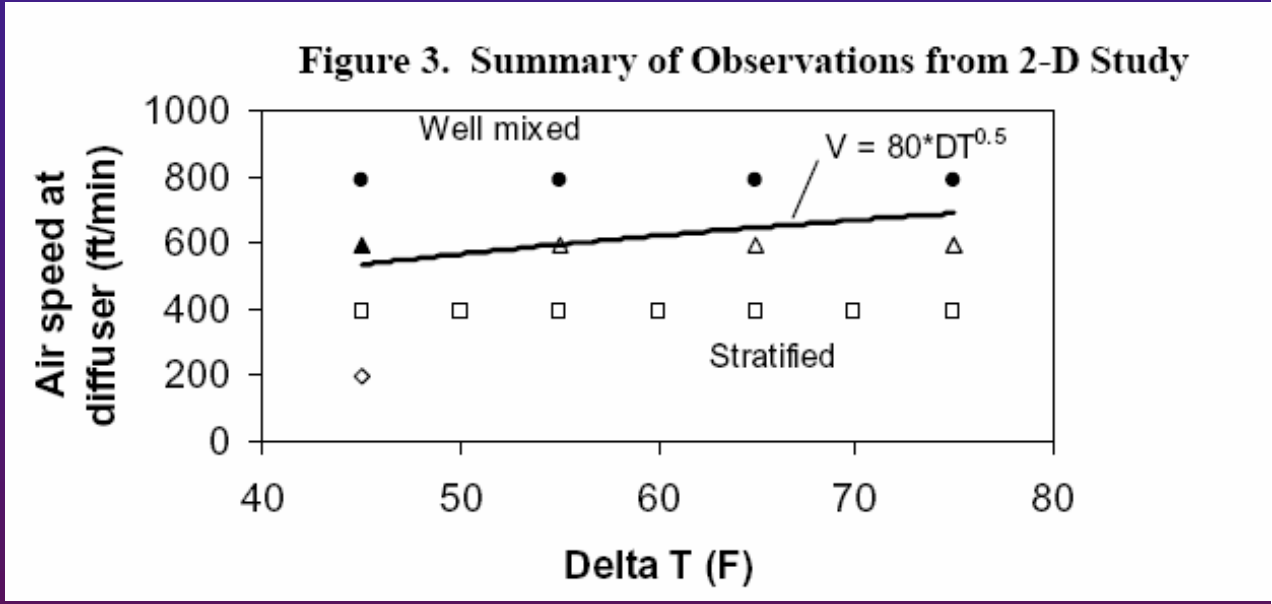


Table 1. Initial Register Specifications (100F Supply @ 470 fpm)

cfm	Area (in2)	Size	Peak Heating Energy Demand (BTU/hr)
50	15	2"x8"	1512
100	31	2"x15	3024
150	46	3"x15"	4536
200	61	2-2"x15"	6048

Simple truths

Higher delta T will meet a given load faster than lower DT

High performance homes have rooms with lower loads

Lower loads and higher DT supplies allow significantly reduced mixing time

All this assumes “perfect mixing” and equivalent delivery efficacy

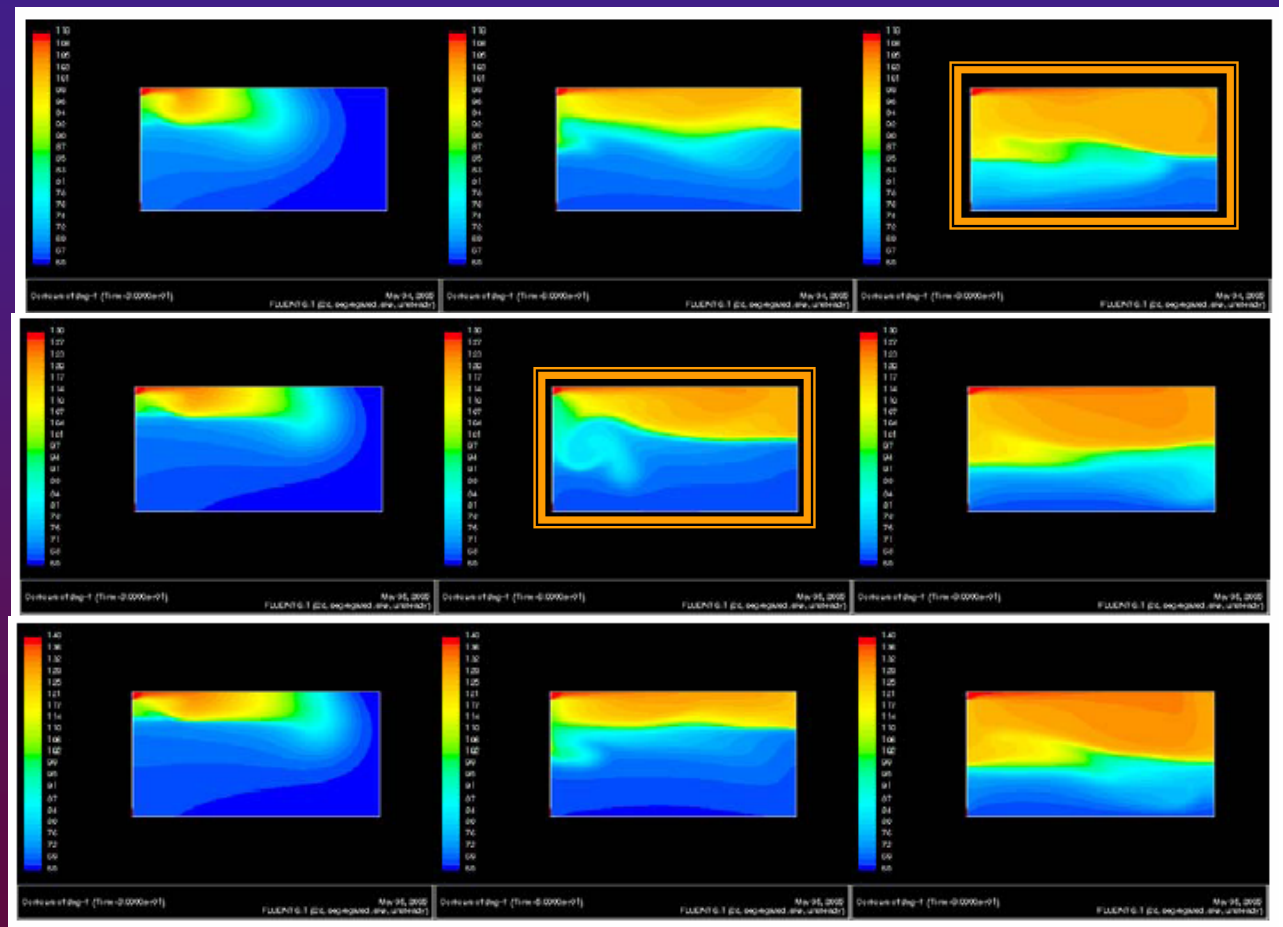
394 f/m supply velocity

Supply air Velocity

110 F

130 F

140 F



time = 30 sec time = 60 sec time = 90 sec

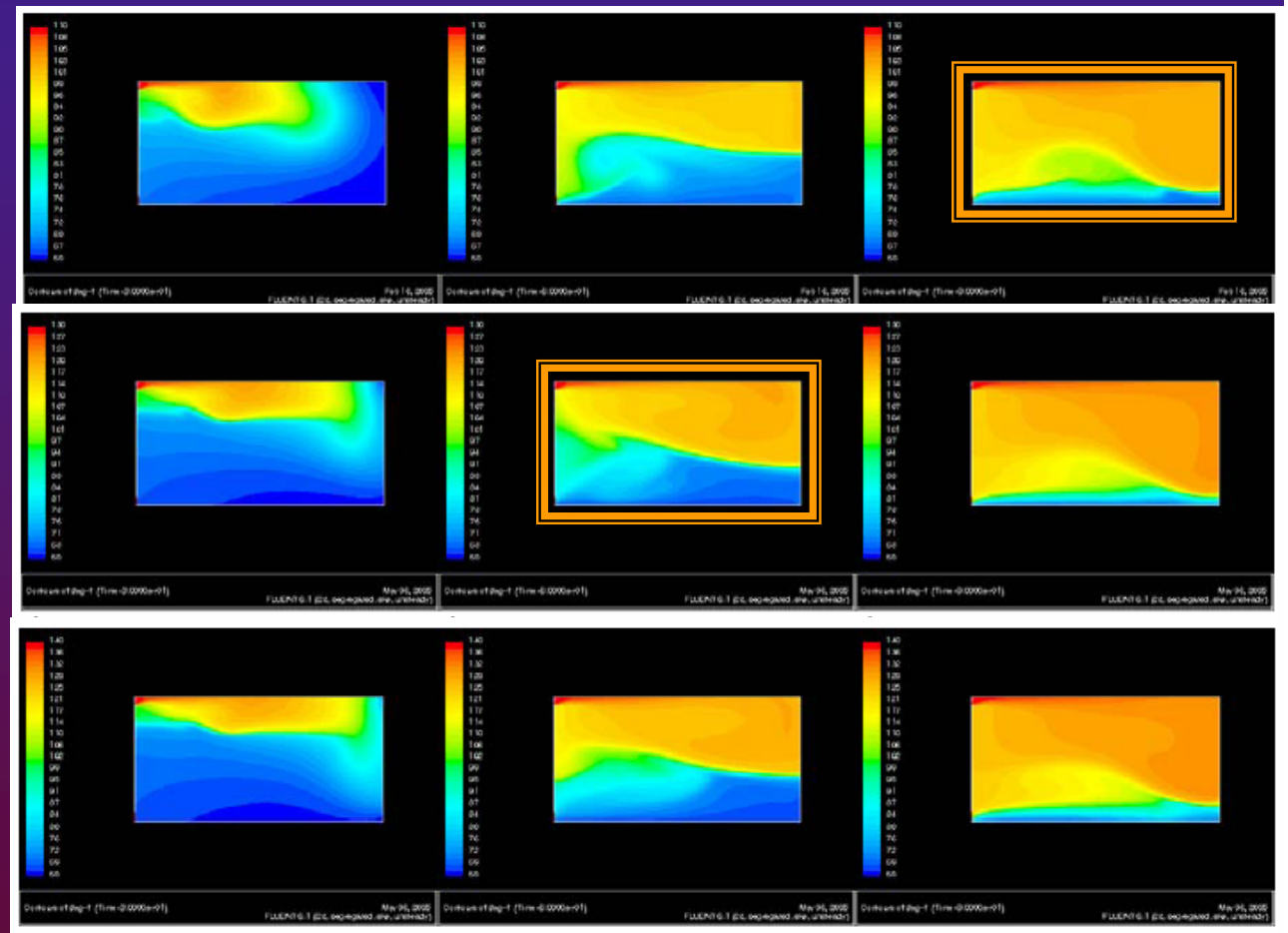
591 f/m supply velocity

Supply air Velocity

110 F

130 F

140 F



time = 30 sec | time = 60 sec | time = 90 sec

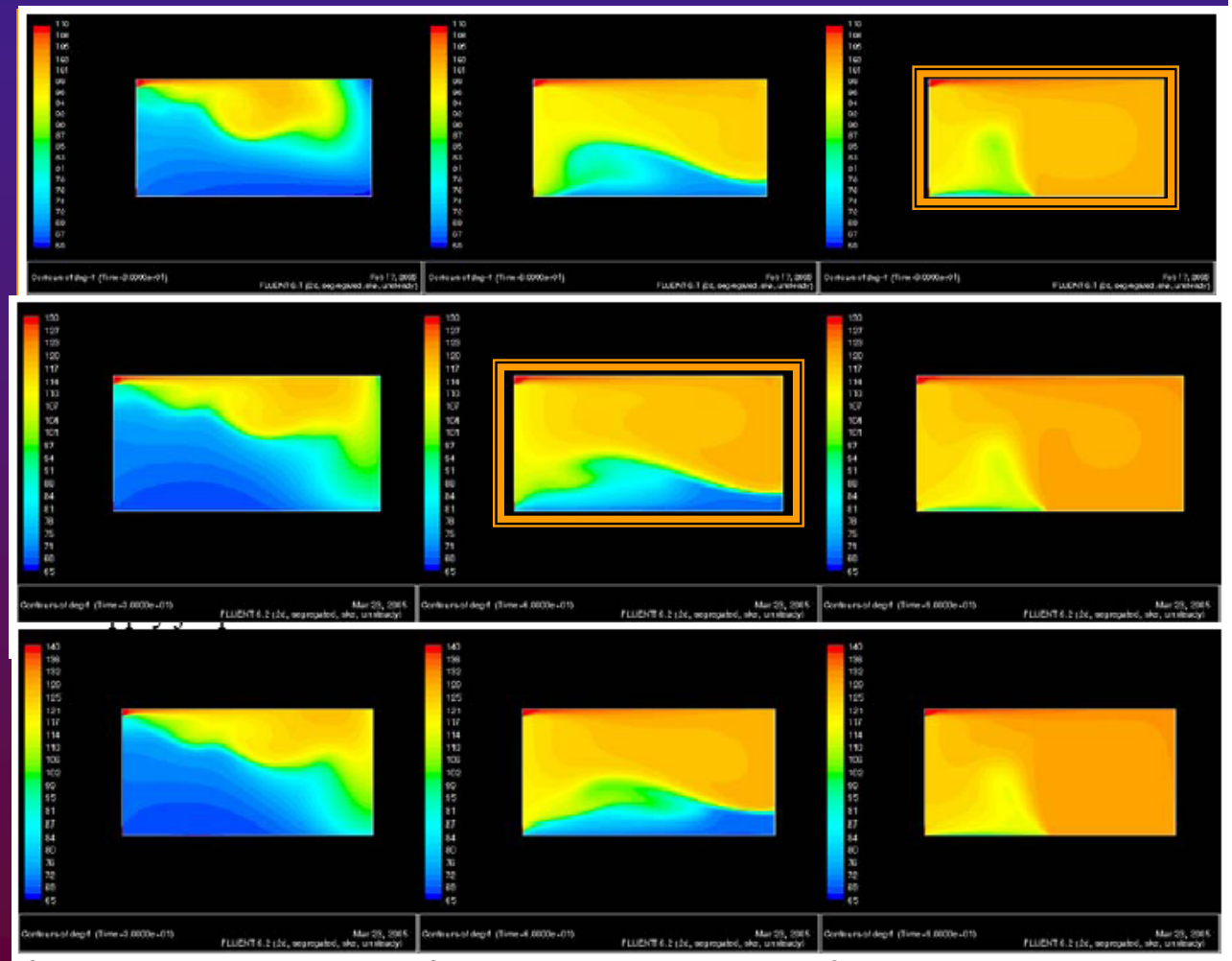
787 f/m supply velocity

Supply air Velocity

110 F

130 F

140 F



time = 30 sec time = 60 sec time = 90 sec

Field Performance of a Zoned Forced-Air Cooling System in an Energy Efficient Home

ASHRAE Standard 55: Thermal Comfort Criteria

The issue is: Can we produce high performance homes (30% to70% Whole House Conservation levels) that can meet comfort expectations?

What conditions of operation, in cooling, must be met to deliver comfort?

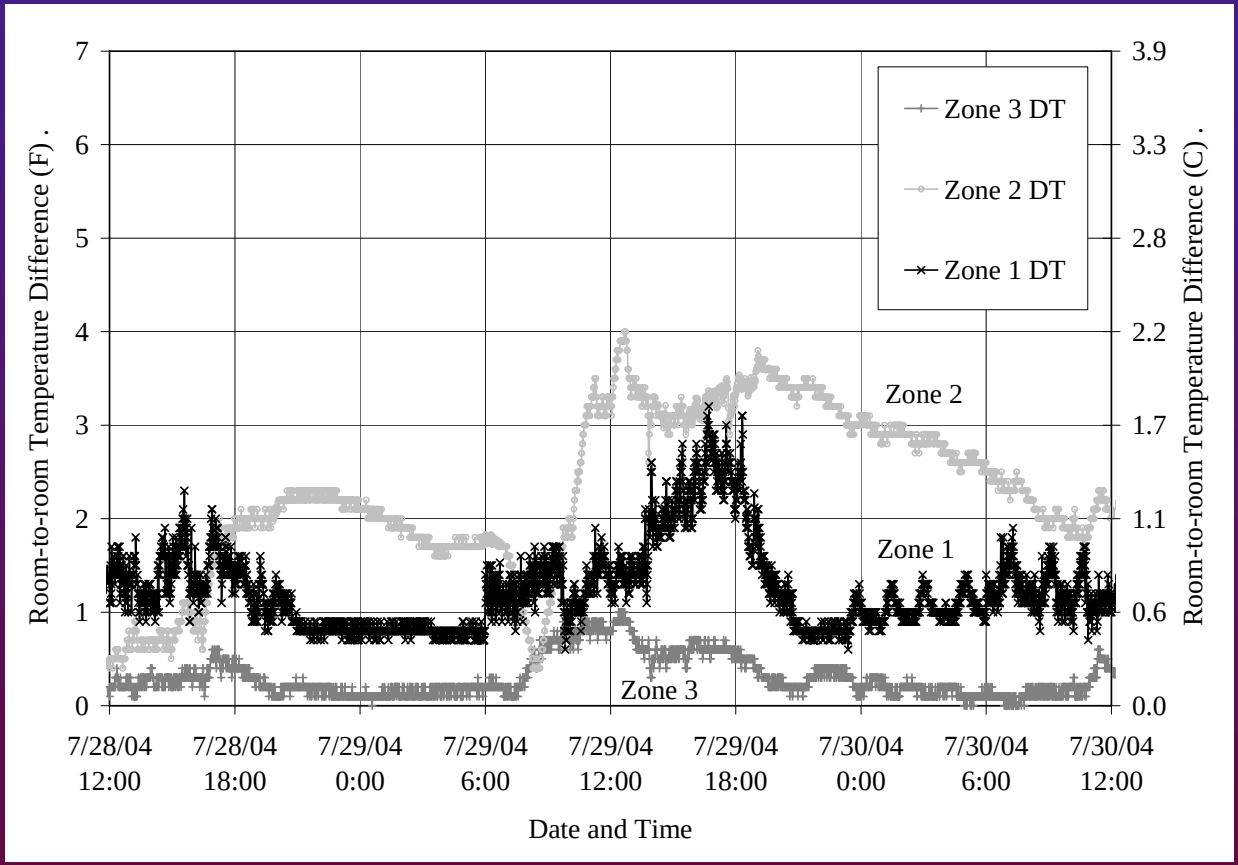
Keith A. Temple, P.E., Ph.D., Member ASHRAE

Two major areas of focus

- Zoned vs non-zoned temperature uniformity
  -
- Heat gain of un-insulated ducts in conditioned space

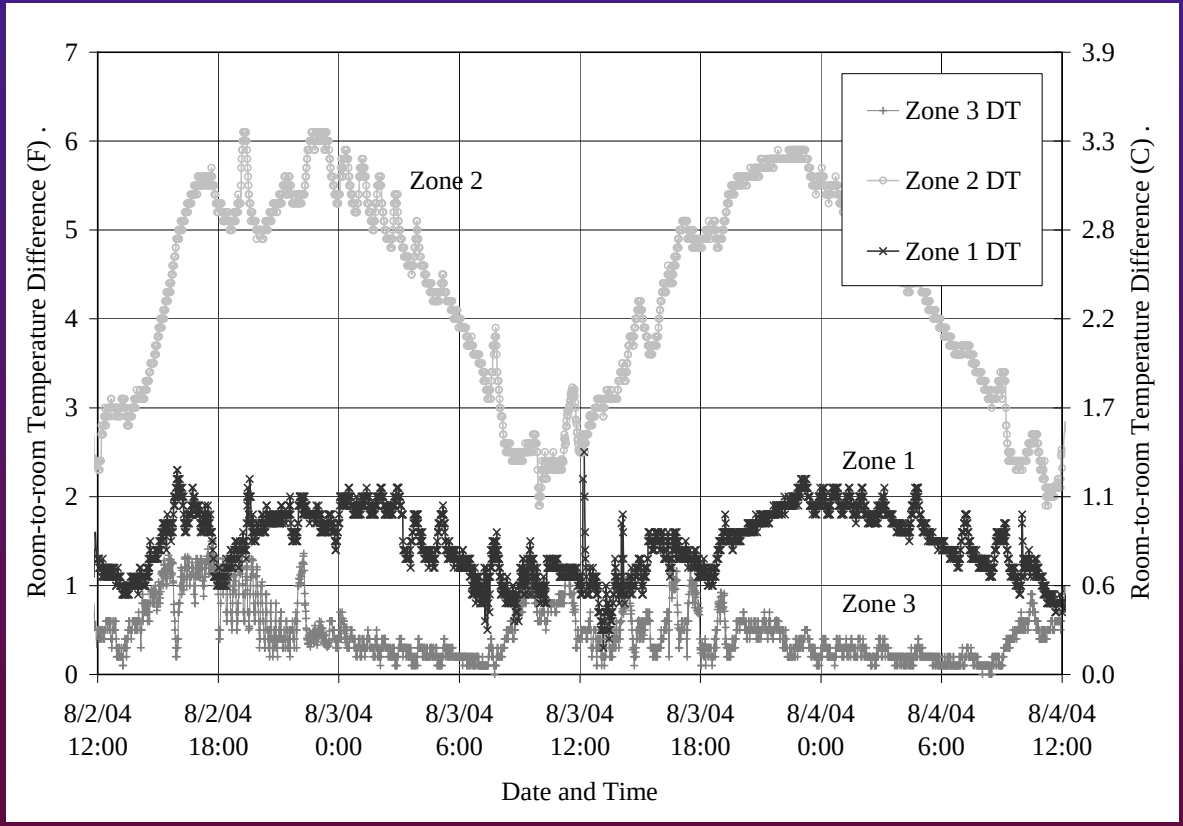
Non-zoned Operation (Case 1) Room-to-room Temperature Differences

Zone 2 deviation is driven by a South West bedroom



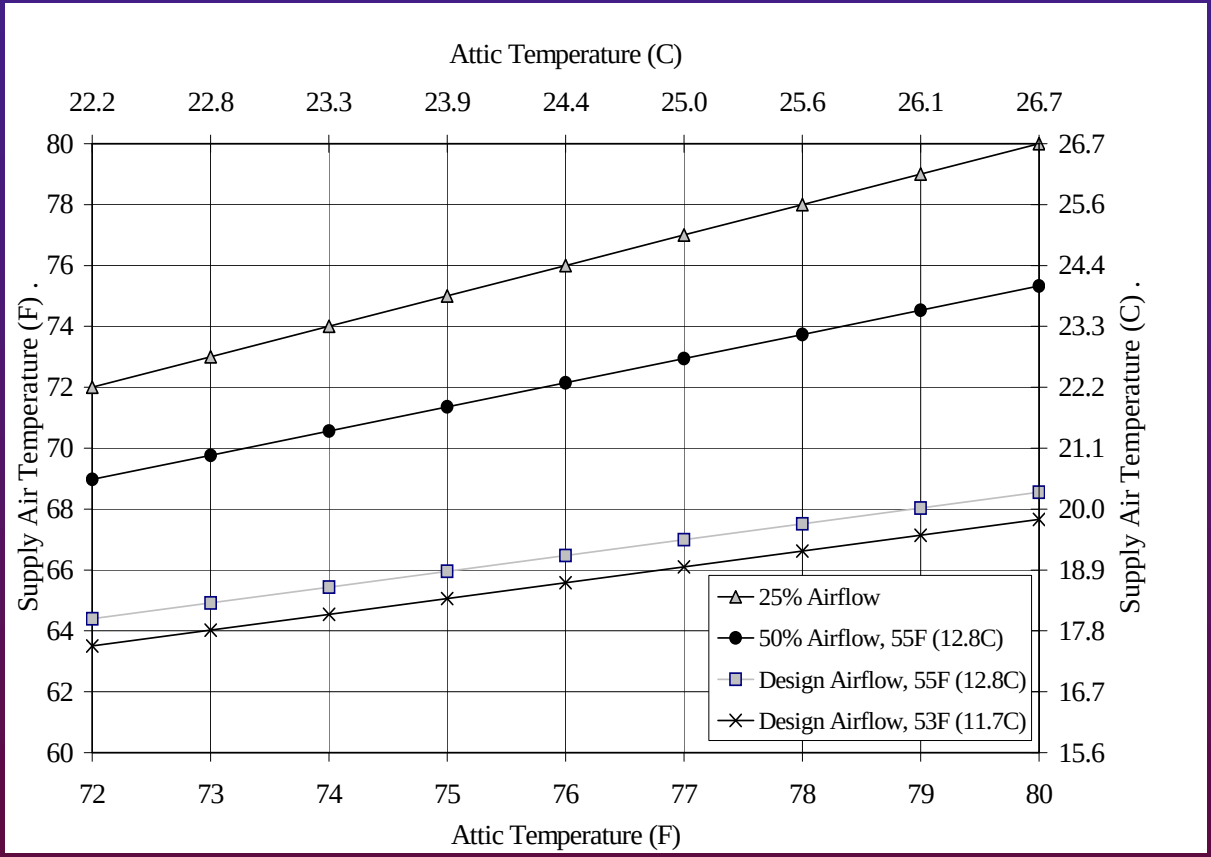
Zoned Operation (Case 2) Room-to-room Temperature Differences

Less connection between rooms and poor thermostat response create conditions that were not as uniform as non-zoned operation



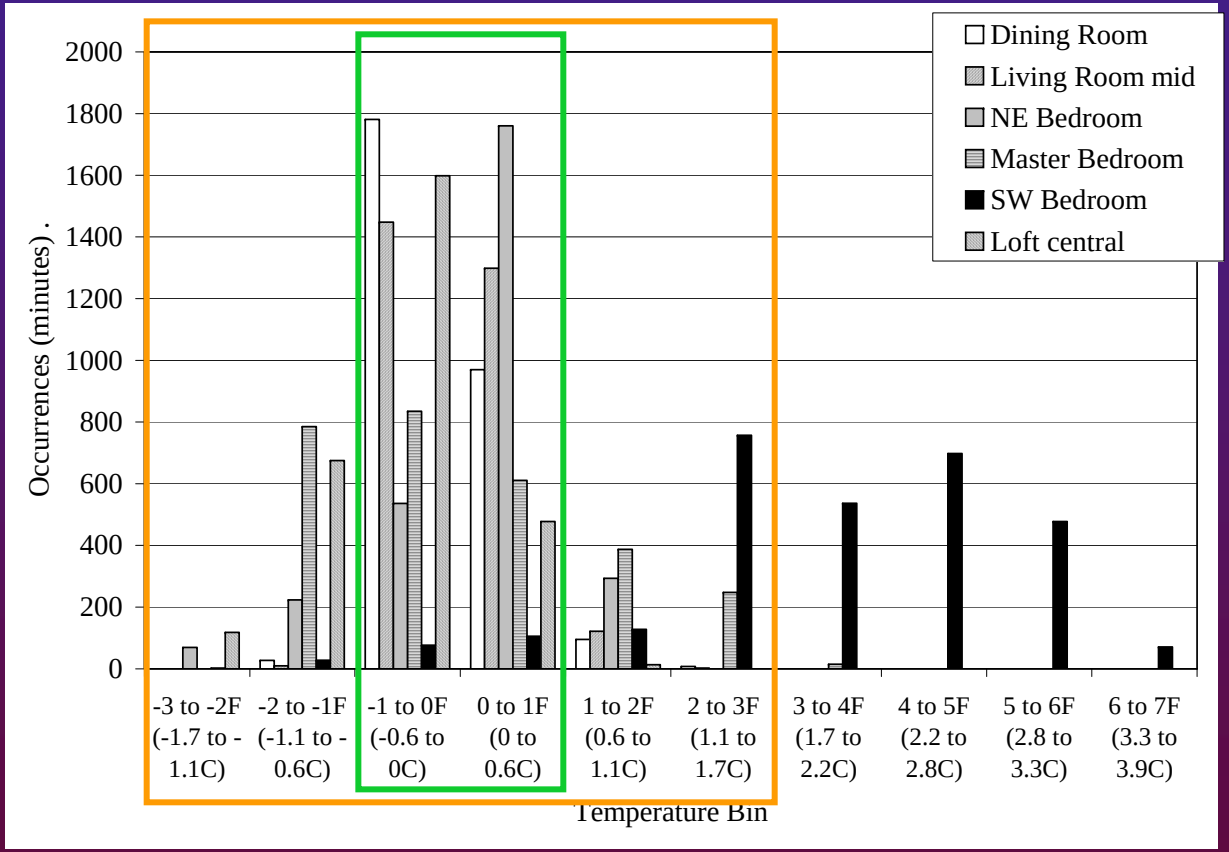
Predicted Supply Air Temperature – SW Bedroom

- Under constant flow
- Eliminating heat gain during stagnation
- Un-insulated ducts passing through attic space inside thermal envelope demonstrate poor efficacy based on flow percentage



Zoned Operation (Case 2) Distribution of Occurrences (minutes) by Setpoint Deviation

- Stratification was not a problem in any room
- Heat gain to un-insulated duct in semi-conditioned space was a problem



Register Performance
Basic Assumptions

1. Outdoor heating and cooling loads are greatly reduced in the high performance house.
2. Of greatest importance, radiant loss/gain from windows is greatly reduced with good glazing.
3. Personal comfort starts from a better condition, air and radiant temperatures are moderated.
4. Lower loads mean reduced air volumes.
5. For furnishability, registers should not be located in the floor or baseboard.

Shorter ducts
Bigger throws

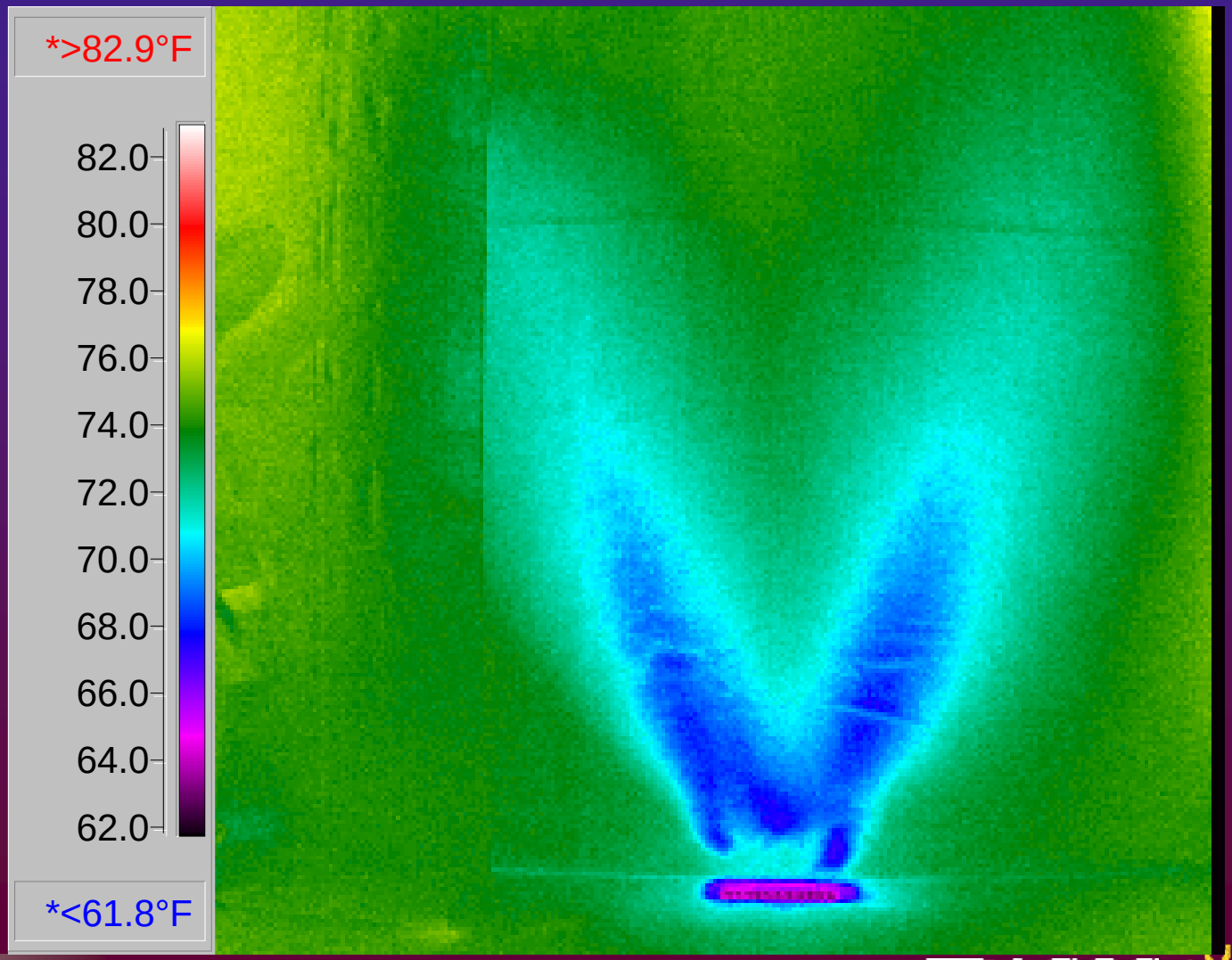
1. Develop a register location strategy that places registers in the ceiling or high on the wall.

2. This strategy must work as well for heating as for cooling.

3. For shorter duct runs, the strategy should locate registers in from the perimeter of the house.

Carrier Test Houses

Carrier Test Houses



Diffuser performance visualization

Test Room

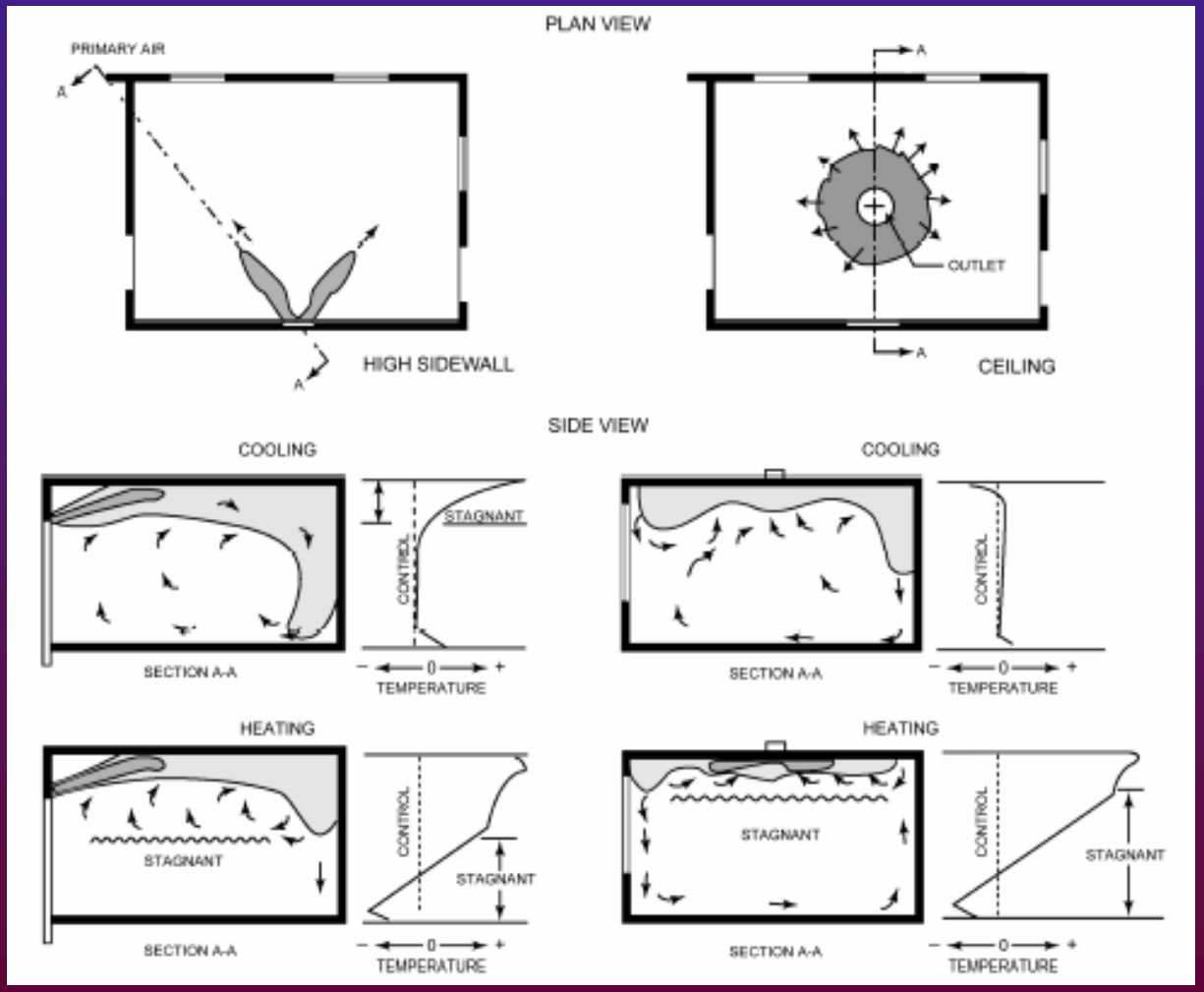
- Heat / cool / ventilation
- Supply: from floor / wall / ceiling
- Return: wall- near / far, high / low, door undercut
- Surface temperature measurement

Air Distribution design

Room Air Distribution

Placement of Registers

- *High sidewall*
  - *throw depends on spread*
- *Ceiling*
  - *consider throw pattern*



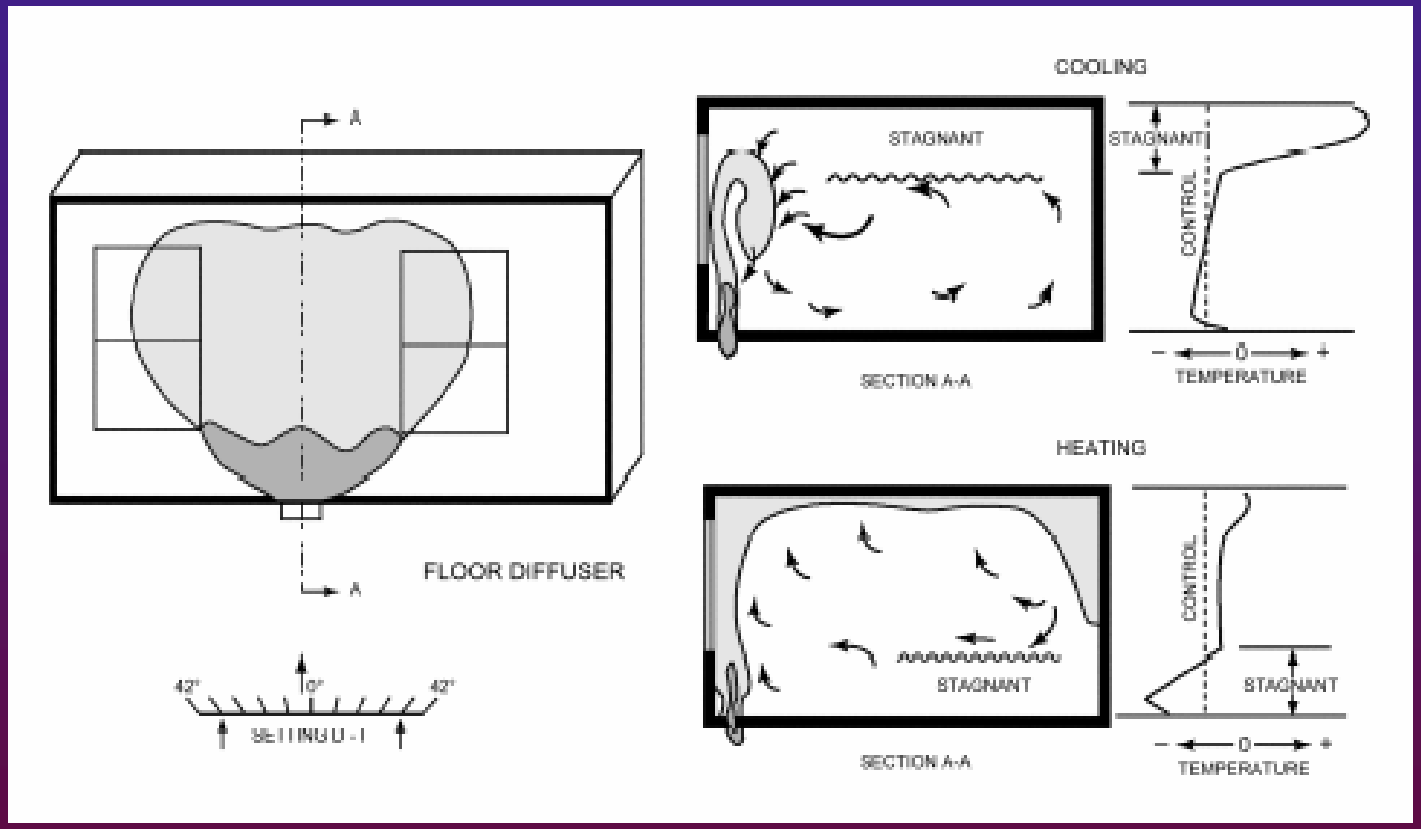
High sidewall and Ceiling (Group A Outlets)

Air Distribution design

Room Air Distribution

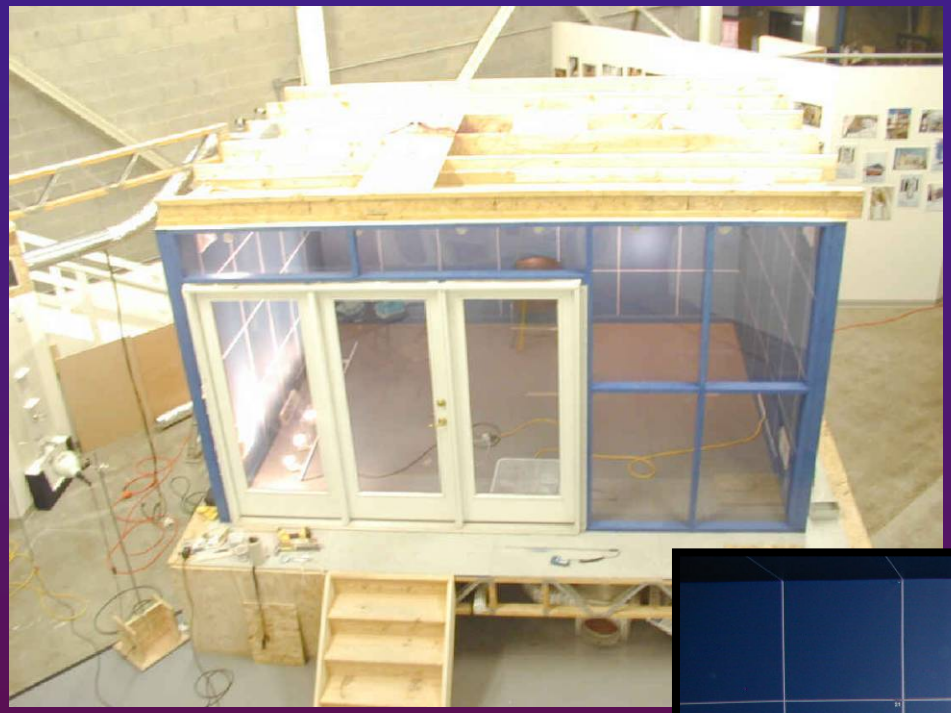
Placement of Registers

- *Floor*
  - *throw depends on spread*



Floor Register (Group C Outlets)

Diffuser performance visualization



Diffuser performance visualization

Floor Diffuser

Baseboard Diffuser

Ceiling Diffuser

High Wall Diffuser

Commercial Diffuser

Isothermal Test

(Basic Performance, as rated by manufacturer)

Floor Register, 100 CFM

High Return

Isothermal Test

(Basic Performance, as rated by manufacturer)

Floor Register, 100 CFM

High Return

Isothermal Test

(Basic Performance, as rated by manufacturer)

Baseboard Register, 100 CFM

High Return

Cooling Test

Baseboard Register, 100 CFM

Low Return

Cooling Test

Ceiling Register, 100 CFM

High Return

Cooling Test

Ceiling Register, 100 CFM

High Return

Heating Test

Ceiling Register, 100 CFM

High Return

Heating Test

Ceiling Register, 100 CFM

Low Return

Conclusions

1. Buoyancy matters. (mostly in cooling)
2. Floor / baseboard at outside wall can give a pool of cold air around the register.
3. High wall / ceiling registers that throw across the ceiling can provide good performance. This area currently under study - the problems are heating performance and surface chill condensation.
4. Floor supply at rear of room works for neither heating nor cooling.
5. Returns are appropriate on an inside wall.

Conclusions (Continued)

6. Low returns are best with high supply for heating or cooling.
7. Low return works as well as a transfer grille.
8. Surface chilling studies have just started. There should be satisfactory design solutions.
9. For good register performance design air flow needs to be near the upper acceptable face velocities.
10. To complete a high performance HCVI system requires the careful design of the supply air plume and the register.

Transition from research to practice

Practice challenges for energy efficient duct design

Long runs have higher friction

Traditional approach is to pick a larger duct diameter

Duct velocity drops too low, LT 500 fpm (Target 900 fpm)

No pressure regain, No throw

Solution: Shorter ducts with throwing registers

- In cooling, good mixing but boot condensation critical
- In heating, need lower DT between supply air and room

Air Distribution Design

Room Air Distribution

Potential Problems

Air Distribution System Design Criteria

System Design Principles

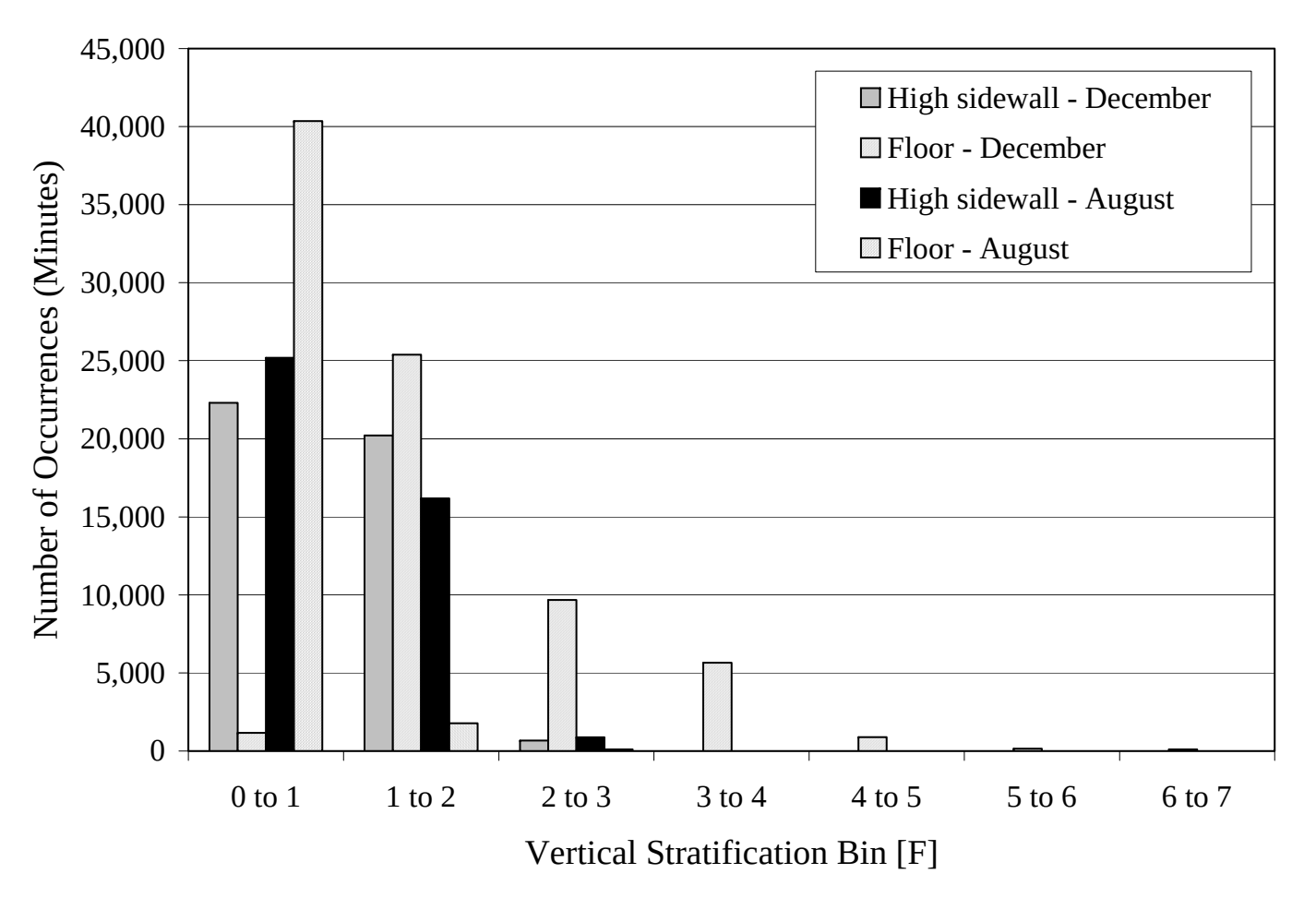
Construction Concerns

Air Distribution design

Room Air Distribution

Placement of Registers

- *Supply is critical*
- *High sidewall (or ceiling) works well in most climates*
- *Provide return path – location is not critical*



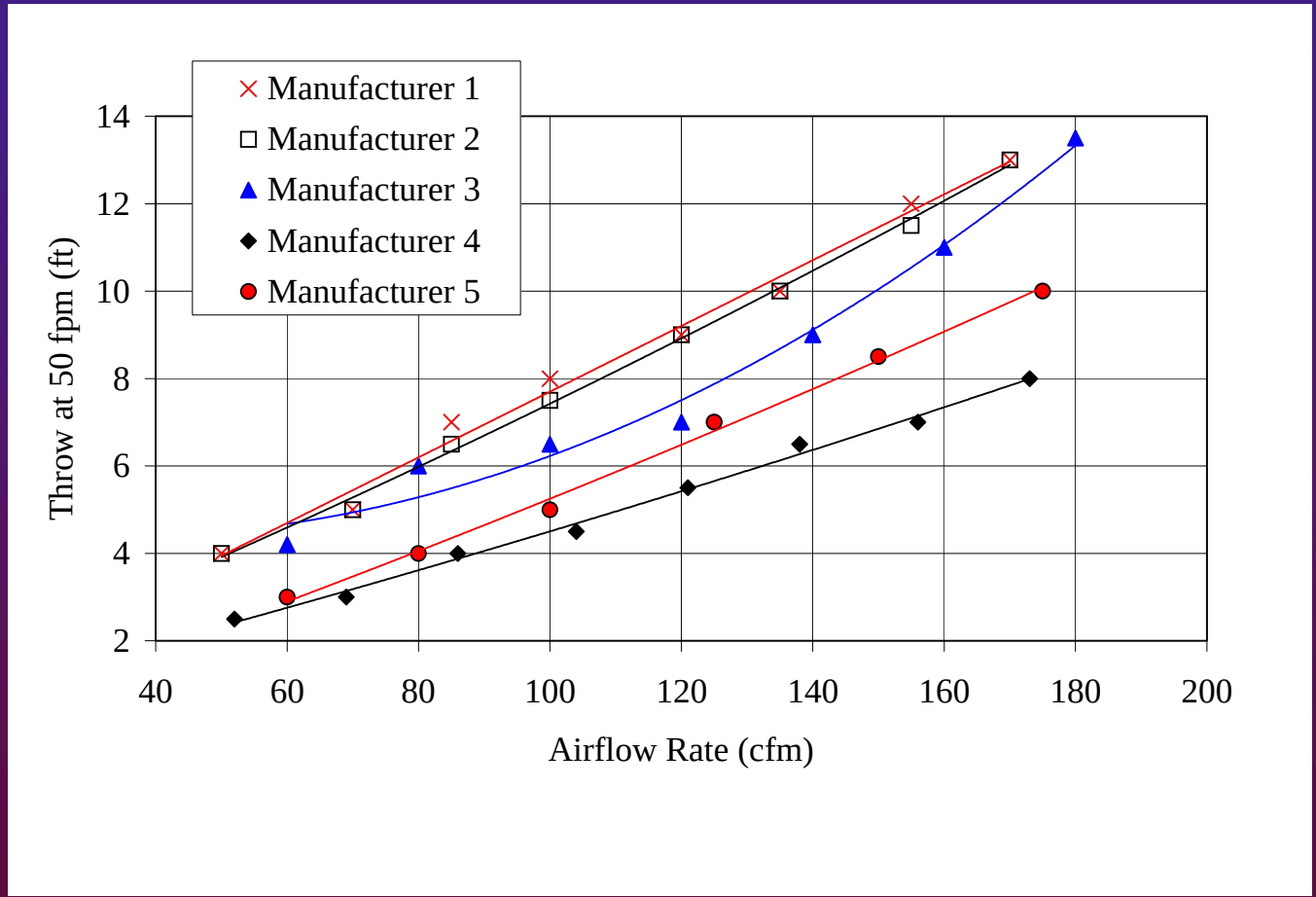
Pilot Home (Pittsburgh PA) Test Data - Stratification

Air Distribution design

Room Air Distribution

Register Selection Criteria

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



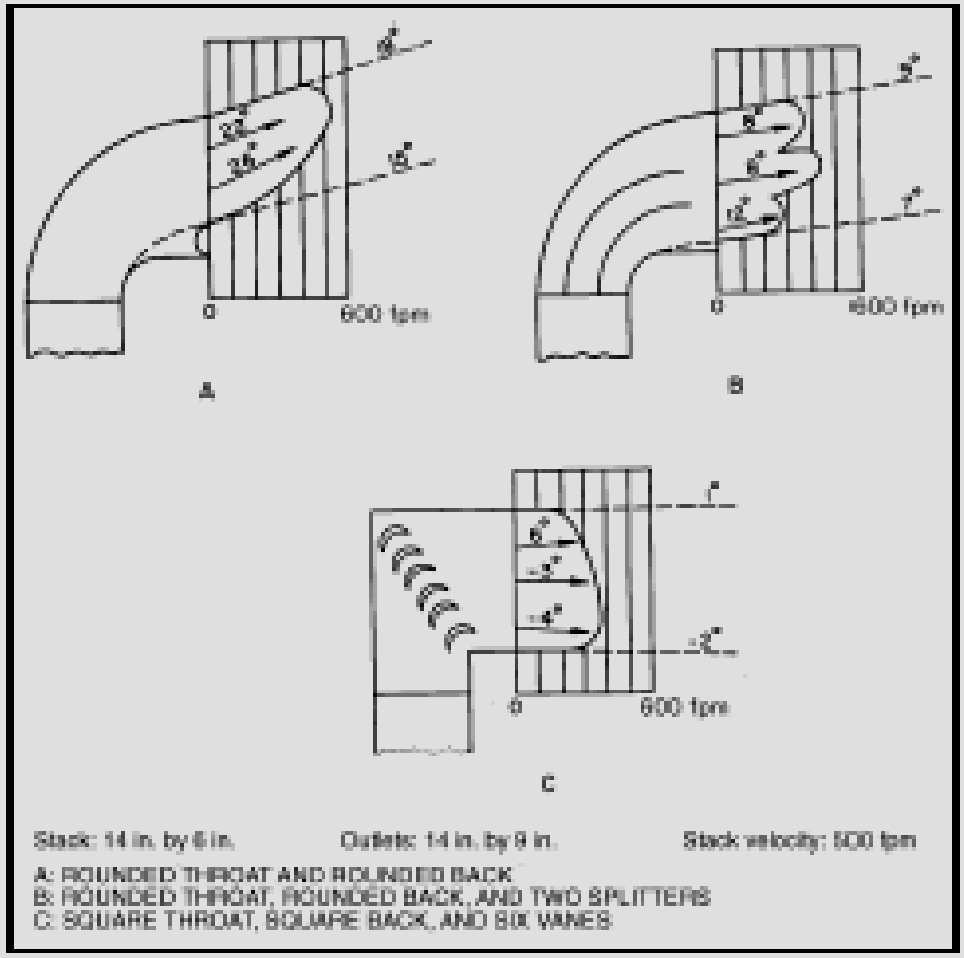
Floor Register Performance (4x10)

Air Distribution design

Room Air Distribution

Impact of Boot on Outlet Performance

- *Velocity Profile*
- *Throw*
- *Pressure Drop*
- *Noise*



So what does this look like in the Field?

Duct Configurations

Use of Proper Fittings

Register locations

Return Characteristics

Air Distribution design

Potential Problems

Poor Room Air Distribution

- *Obstruction by furniture or draperies*
- *Poor throw due to low airflow*

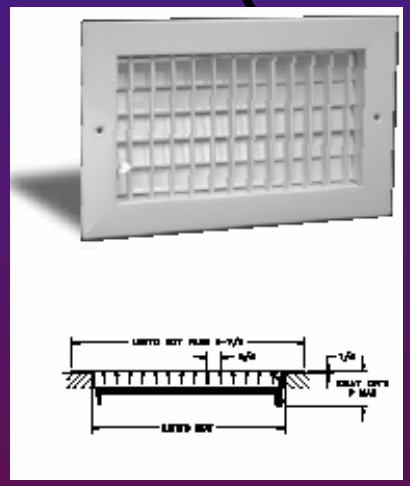
Air Distribution design

Room Air Distribution

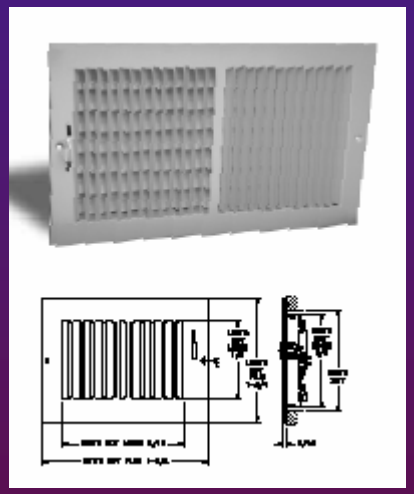
Register
Selection Criteria

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

Higher performance does not have to cost more



900 Commercial



600 Residential

Air Distribution design

Construction Concerns

Provide return path

- *Ducted return main*
- *Return path for each room*

Air Distribution design

System Design Principles

Locate system in conditioned space or insulate well

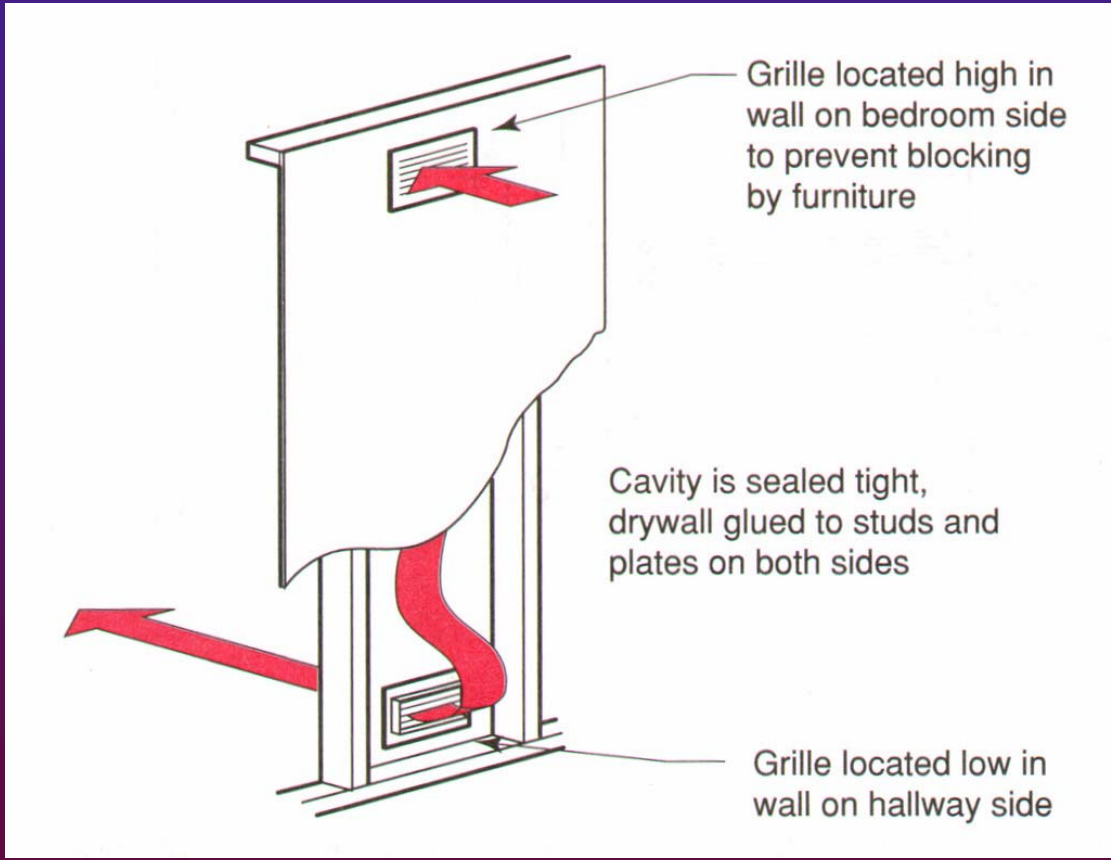
- *Basement*
- *Un-vented crawlspace*
- *Structure/ceiling space of main floors*

Air Distribution design

System Design Principles

Provide return path

- *Ducted return main*
- *Return path for each room*
- *Twice supply dimension*



Transfer Grille

Air Distribution design

System Design Principles

Provide return path

- *Ducted return main*
- *Return path for each room*
- *Twice supply dimension*

Jump Duct above door

Air Distribution design

Potential Problems

Low System Airflow

- *High system pressure drop*
- *Wrong fittings*
- *Critical branch*
- *Poor fan performance*

Many systems require return from both sides of the unit

Air Distribution design

Potential Problems

Low System Airflow

- *High system pressure drop*
- *Wrong fittings*
- *Critical branch*
- *Poor fan performance*

Convenient to build, but not convenient to design

Air Distribution design

Potential Problems

Low System Airflow

- *High system pressure drop*
- *Wrong fittings*
- *Critical branch*
- *Poor fan performance*
-

Air Distribution design

Potential Problems

Noise

- *High face velocity at register*
- *Poor fitting design*
- *No return duct system*

Grills in doors and through walls restrict flow and do nothing to capture fan noise

Air Distribution design

Potential Problems

Noise

- *High face velocity at register*
- *Poor fitting design*
- *No return duct system*

Door grills have less than 25% free area

Air Distribution Design

Design Guidance

External static pressure is less for higher efficiency system!

Balance distribution by fiction proportioned run-outs

Shorter ducts with higher velocity

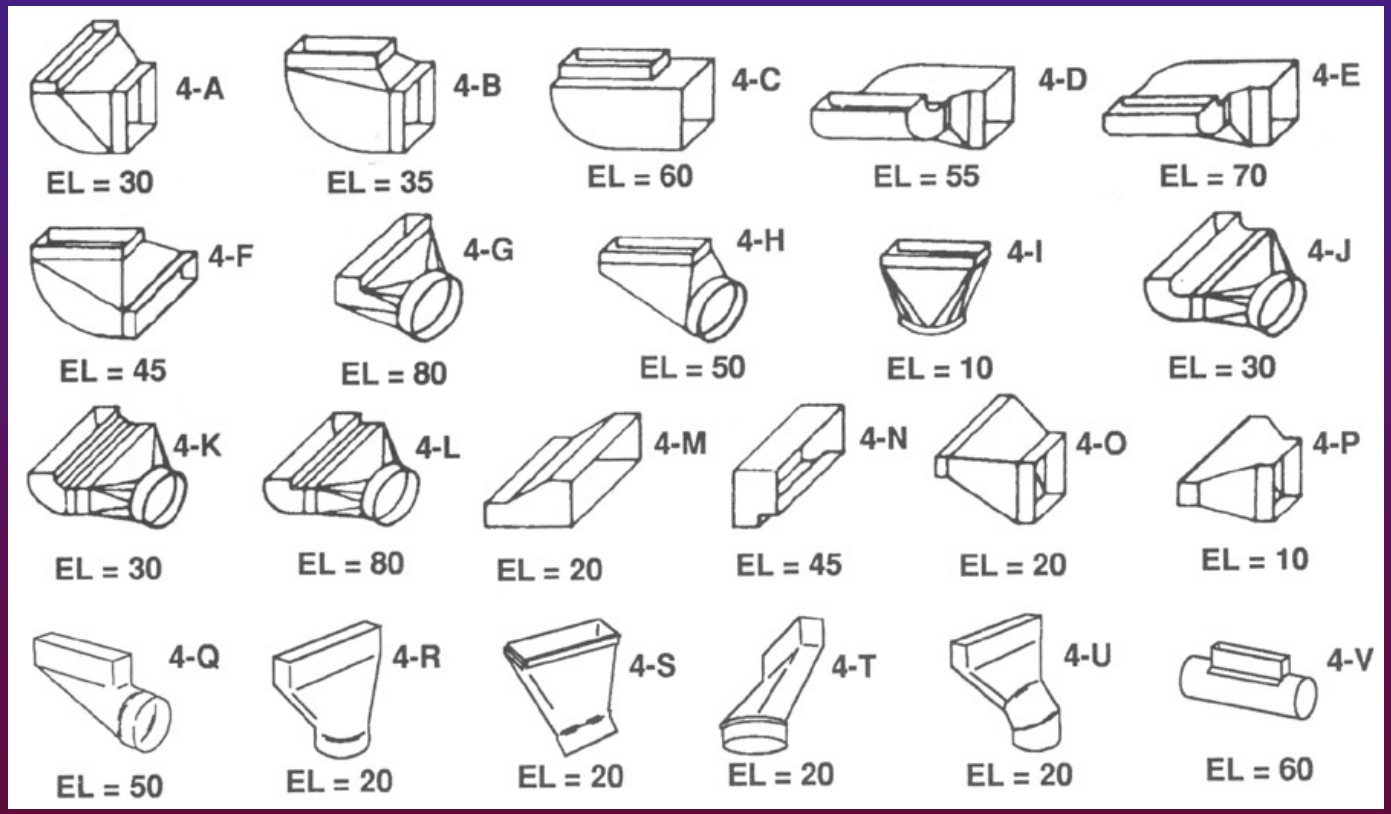
- Allows pressure regain / balancing
- Higher velocity comes from smaller ducts
- Cost less and use fewer resources

Air Distribution design

System Design Principles

Design Fittings

- *Plenum*
- *Branch takeoffs*
- *Elbows*
- *Boots*



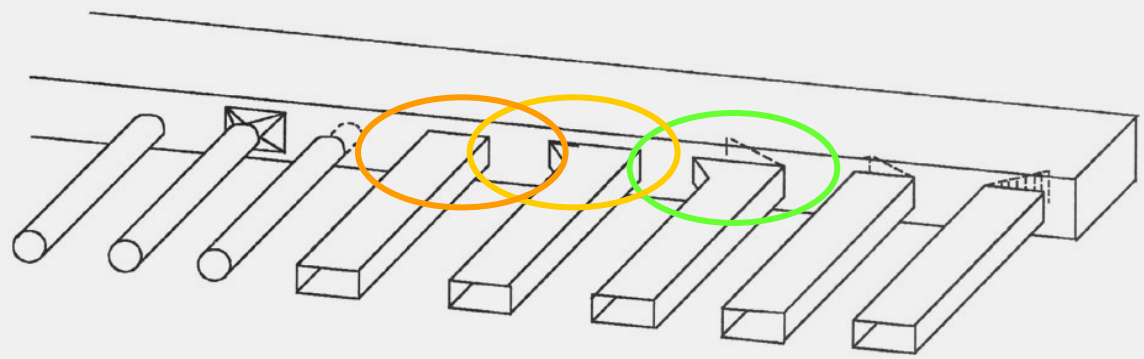
Each element contributes to loss in flow

Air Distribution design

System Design Principles

Balance branch run-outs

- *Convenience*
- *Tradition*
- *Performance*



EL Values		Number of Downstream Branches to End of Trunk Duct or Number of Downstream Branches to a Trunk Reducer					
Fitting		0	1	2	3	4	5 or More
	2-A	35	45	55	65	70	80
	2-B	20	30	35	40	45	50
	2-C	65	65	65	65	70	80
	2-D	40	50	60	65	75	85
	2-E	25	30	35	40	45	50
	2-F	20	20	20	20	25	25
	2-G	65	65	65	70	80	90
	2-H	70	70	70	75	85	95

Note: If the trunk has a reducer, count down to the reducer; then begin counting (again) after the reducer

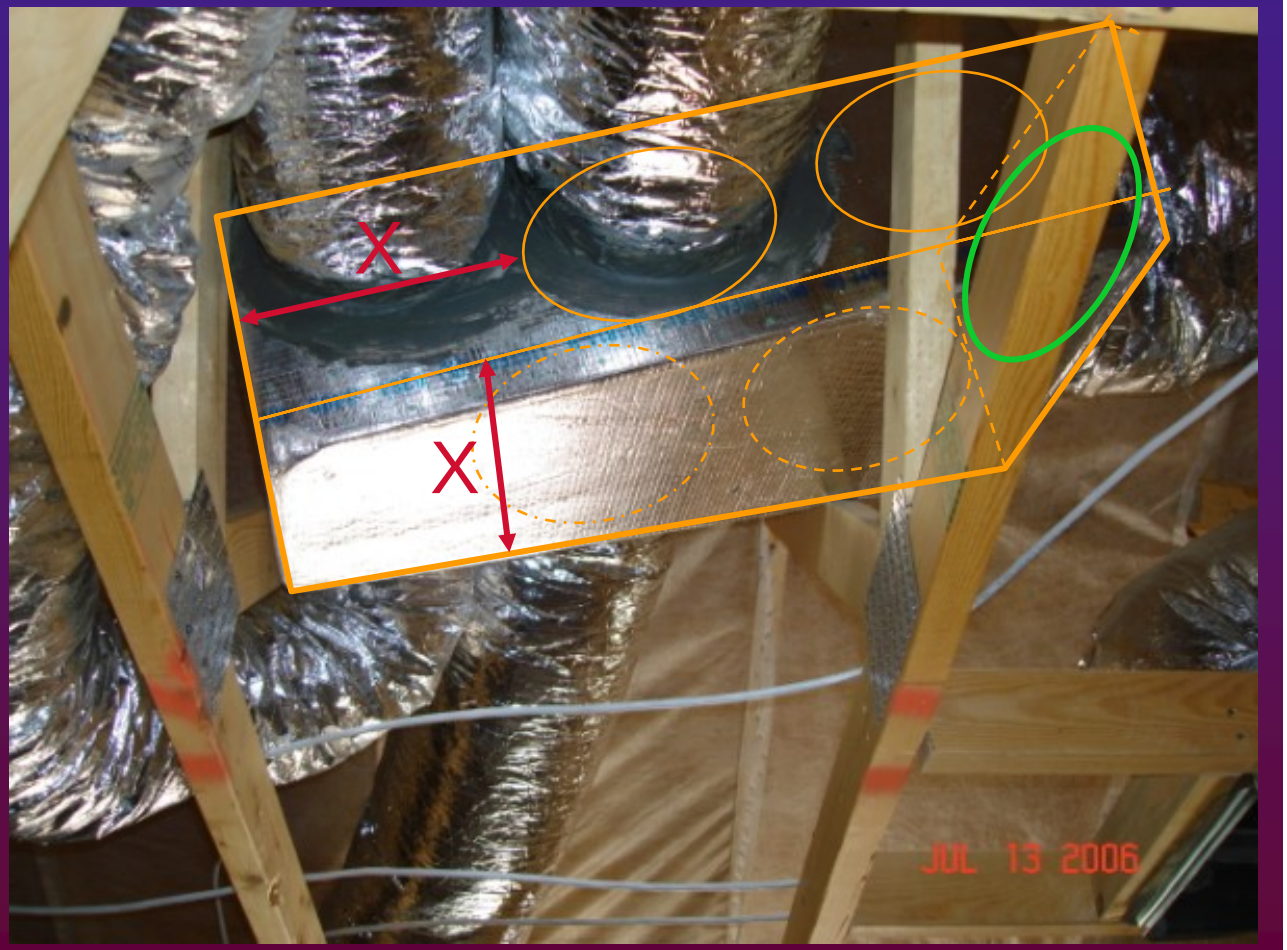
Pressure regain plenum

Round metal duct section at end of flex run out creates a plenum. The blank end converts velocity pressure to static pressure yielding relatively uniform pressure to all ducts.

Flow is proportioned by downstream friction and opening size

Pressure regain plenum

- Plenums must create equal pressure across openings to yield proportional flow
- Do not place outlets in last third of plenum. This section must convert velocity pressure to static pressure.
- Duct in NO Zone drain off distribution energy



Splitter Boxes

- Make splitter boxes as small as needed to just fit the supply duct
- For square splitter boxes, do not take a duct off opposite supply duct connection

Distribution Strategy

These are very hard to balance.

Equal size ducts on opposite sides of inlet/outlet, create no or little static pressure to force distribution to side branches

In Round duct, two takeoffs on same side shadow each other and reduce flow to second duct

Summary Points

High performance homes demand rethinking

Registers must deliver mixing

Distribution systems are longer per cfm

Fittings and routing must be critically viewed

Returns must be designed

Thank You

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