U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building America U.S. Department of Energy

Building America

High Performance HVAC: Low-Load and Plug-n-Play HVAC Systems

March 23, 2017

Moderator:
Linh Truong– National Renewable Energy Laboratory

Panelists:
Andrew Poerschke – IBACOS
Robert Beach – IBACOS

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Agenda

- ✓Welcome and Introductory Remarks
- ✓Overview of Building America (buildingamerica.gov)
  - Linh Truong - National Renewable Energy Laboratory
- ✓Presentations
  - Andrew Poerschke - IBACOS
  - Robert Beach - IBACOS
- ✓Questions and Answers
- ✓Closing Remarks

Building America

Building America Website:

- Program information
- Top Innovations
- Climate-specific case studies
- *Building America Update* newsletter
- Building America Solution Center
- Publications Library

www.buildingamerica.gov

Andrew Poerschke, Specialist – Innovation Programs, IBACOS

Andrew conducts research in building performance and has advanced energy modeling and computational analysis experience. Andrew has conducted research on innovative space conditioning technologies for the last five years. Andrew uses the tools of engineering to guide the performance and design of new products for the homebuilding and HVAC industry.

Rob Beach, Specialist – Innovation Programs, IBACOS

Rob is an expert in 3D modeling and systems analysis. He has over 16 years of modeling, prototyping and design experience. With a background in design and fabrication focused on computational methods and computer-numerically-controlled machining, Rob brings a diverse experience and skillset to the table, enabling innovative thinking and creative solutions. Rob has contributed to numerous space-conditioning, enclosure design and market analysis projects with a specific focus on modeling, graphics and data analytics.

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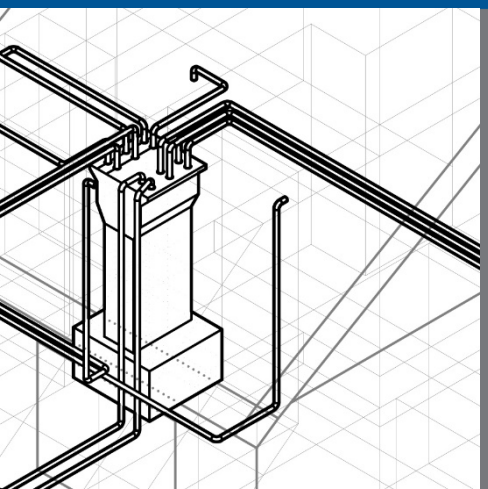
Plug and Play Duct System

Robert Beach
Specialist, Innovation Programs

Andrew Poerschke
Specialist, Innovation Programs



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Agenda:

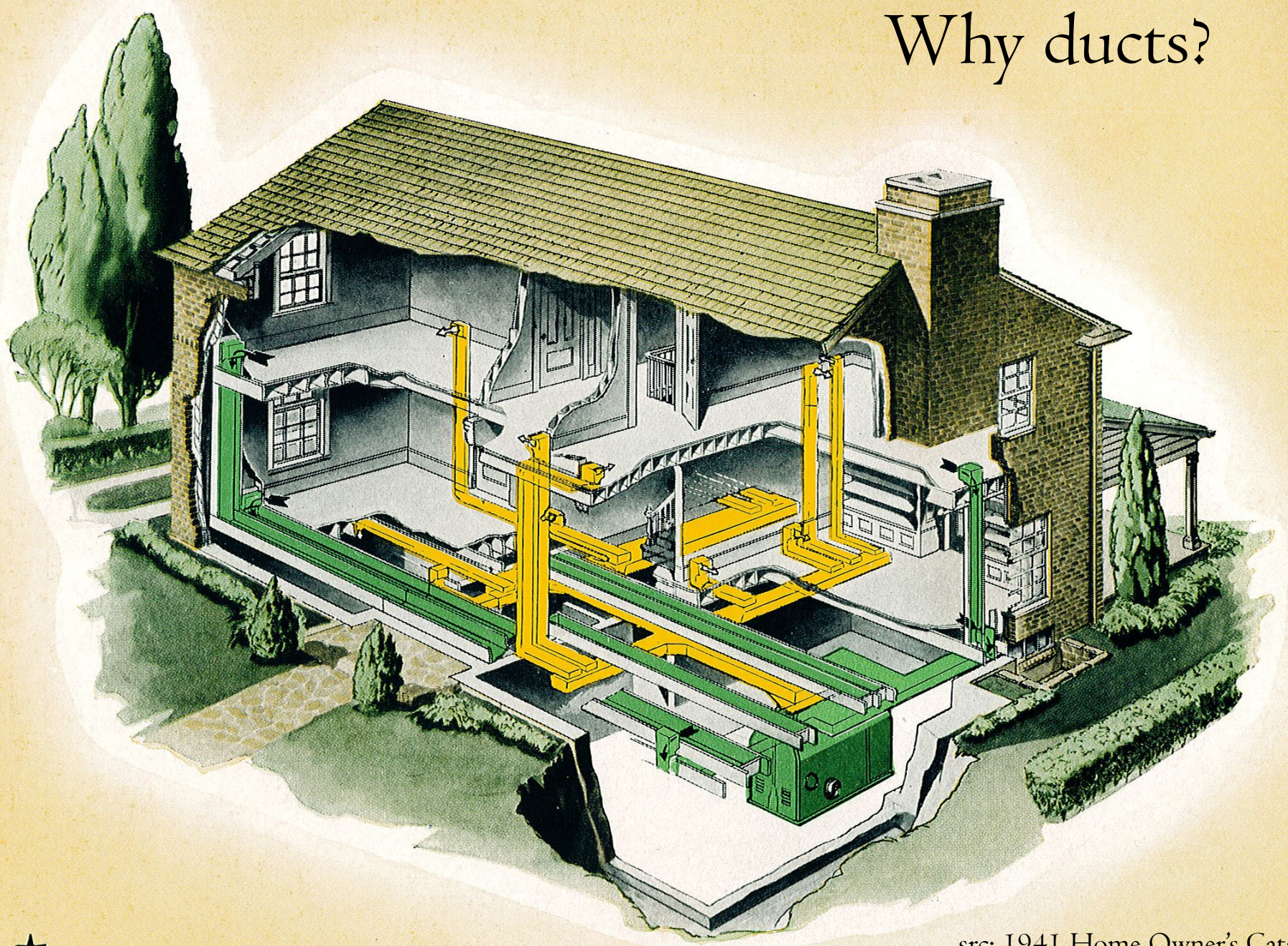
Background

Plug and Play Concept

Building America Project

Conclusions

Why ducts?



src: 1941 Home Owner's Catalog

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Buildings are changing.

Trends and Challenges in HVAC

Shrinking loads and airflows

Desire, but difficulty bringing conventional ducts into conditioned space

Maintain velocity and mixing across range of system operation states

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Trends and Challenges in HVAC

Industry and labor are changing.

Cost and complexity of existing design methods

Challenges in finding skilled installation labor

Complicated and time-consuming commissioning and rating

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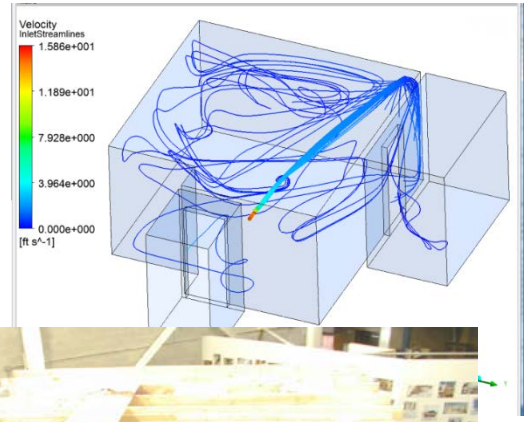
25 Years of HVAC Research



IBACOS has been conducting research on innovative HVAC methods for 25 years.

Background

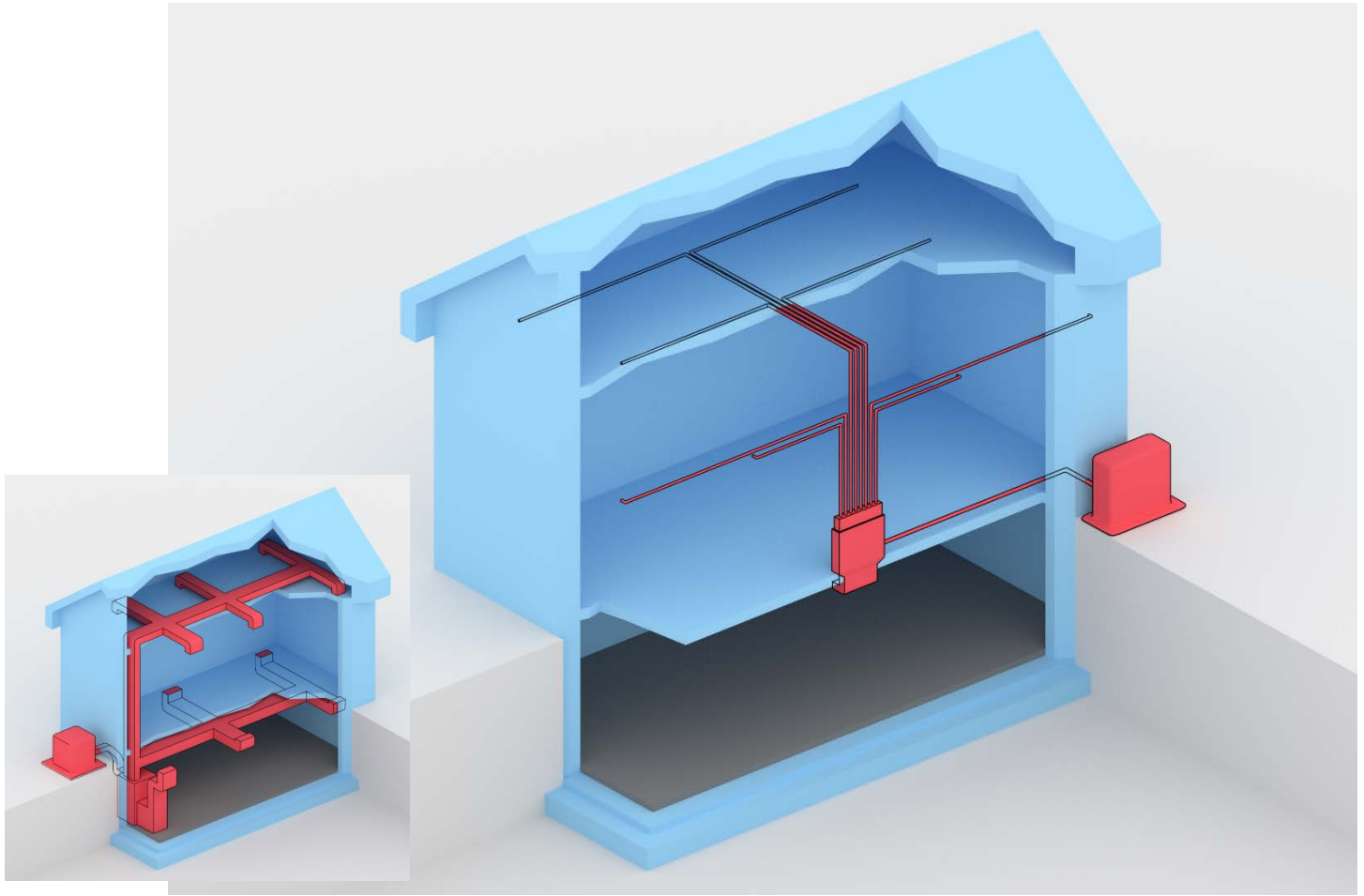
Plug and Play Concept

Building America Project

Conclusions

Plug and Play (PnP) Air Delivery System Concept

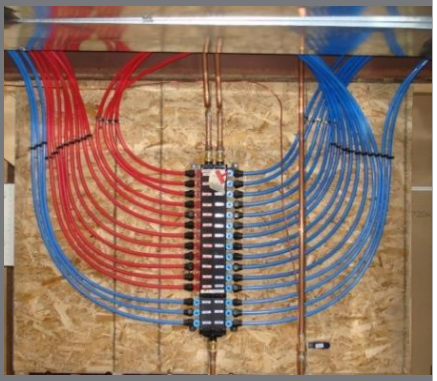
- Home Run Duct System
- Simplified Design Process
- Single Duct Size
- Single Fitting
- Simple Installation

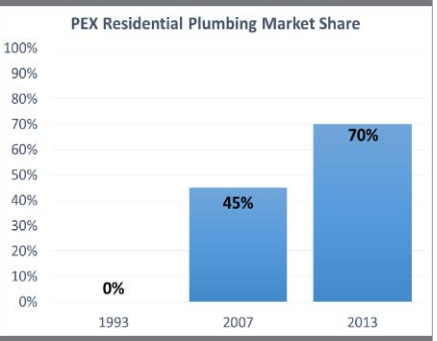


PnP Air Delivery System Concept

- Small Diameter Ducts (2 - 3”)
- Semi-rigid (plastic) material
- Central and Accessible Air Manifold
- Leak Free Duct Product

Plug and Play Opportunity





The Plug and Play duct system could revolutionize ducted air distribution systems in the same way PEX manifold piping systems impacted plumbing distribution.

- PEX costs 25% - 45% less than copper, installed
- Rapid claim to majority market share

Residential ductwork is ~ $1.2 Billion ($1200/home for ductwork * 1M homes) market annually

Goals of Building America Project

- Demonstrate the advantages of the plug and play system over traditional residential duct systems
- Develop a straightforward design methodology
- Engage with industry in overcoming barriers to market adoption (Codes, builders, manufacturers)
- Demonstrate early estimates on labor and cost savings
- Addresses Optimal Comfort Systems for Low-Load Homes Roadmap


Design Method
Component Testing
Lab House Testing
Simulations
Costs, Codes,
Conclusions

Major Parameters

Need to understand significant parameters for ideal distribution.

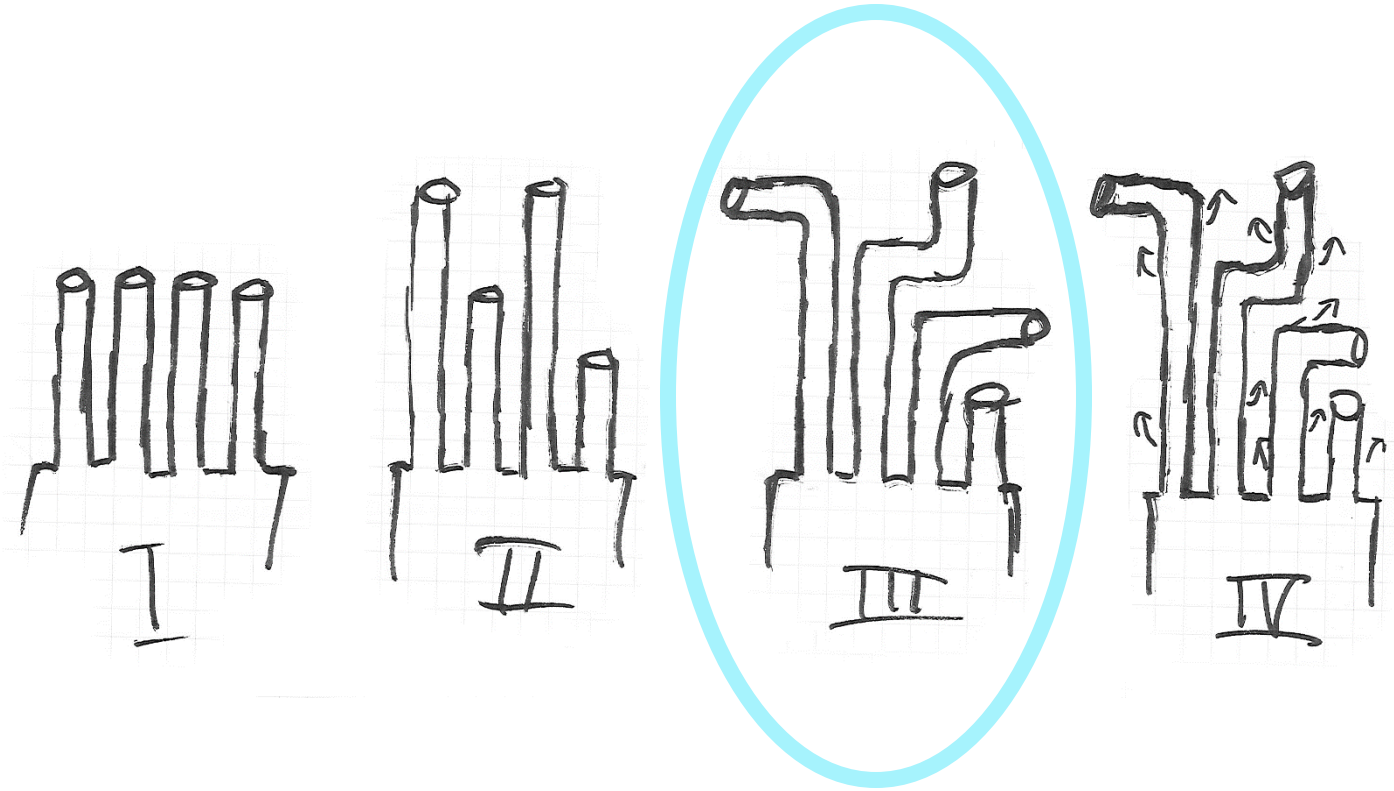
Based on existing science

- Duct diameter
- Duct material (roughness and insulation)
- Duct layout
- Design and installation process

Design Method

Four approaches considered

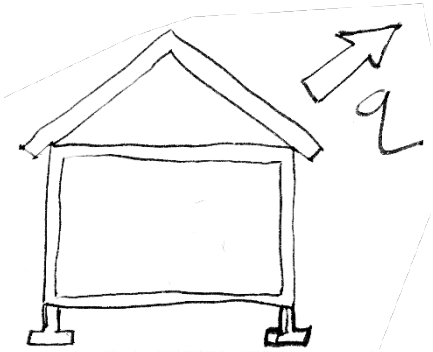
Need to understand pressure and flow relationship for different materials.

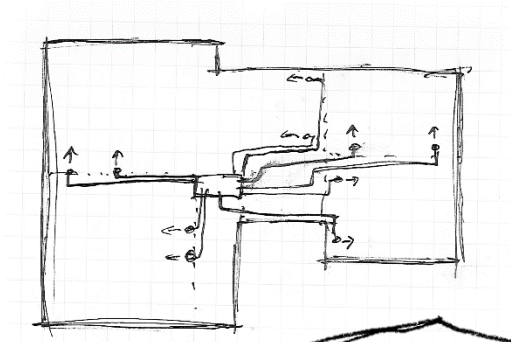


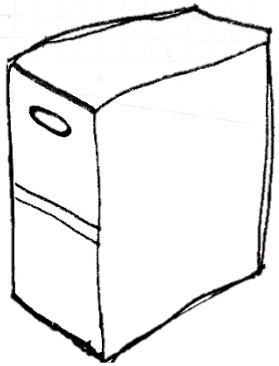
Design Method

- Manual J
- Layout
- Manual S
- Design Tool - Replaces Manual D

$$Q = \frac{Pa^{\frac{1}{n}}}{C * L}$$







Plug-and-Play Home Run Manifold Design Tool

v 0.1

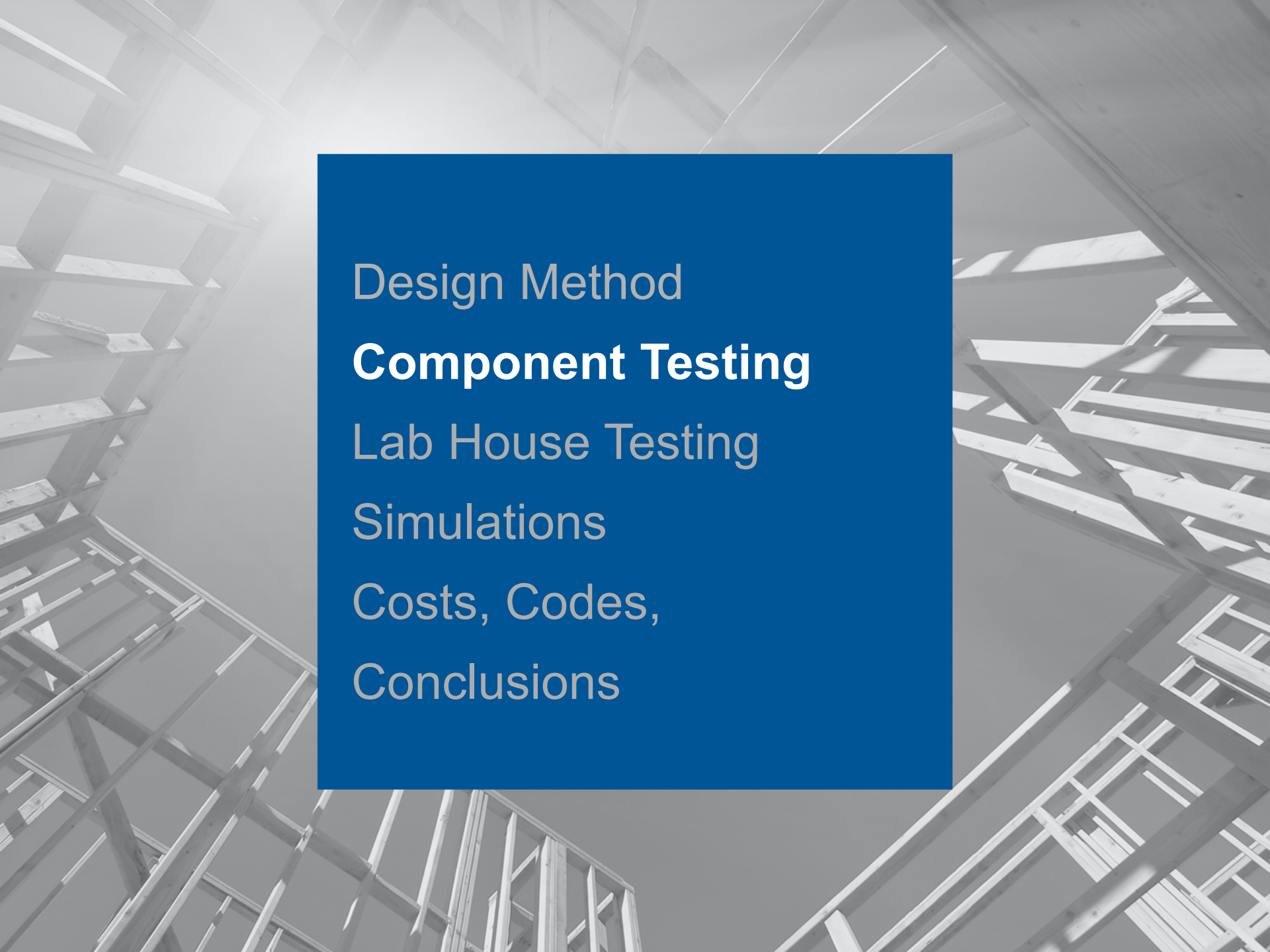
Project

Nominal CFM	26	(based on 30' L, 60 Pa)
Available Pressure	0.35	in. wc. (from manual S) (minus 0.1" for manifold)
Heating factor	0.0231	Btuh / CFM
Cooling factor	0.0268	Btuh / CFM

#	Room	Htg Load (Btuh)	Clg Load (Btuh)	CFM	Len (ft.)	Elb	Ducts
1	Master Bedroom	2365	2316	55	29	5	2
2	Bath 2	642	220	15	12	3	1
3	Bedroom 2	2025	1500	47	15	4	2
4	Powder	798	620	18	22	3	1
5	1st Floor	6489	4486	150	16	3	5
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
	Total:	12319	9142	285	94	18	11

Select Material: 2" PVC

EL of 90	2	
Pipe Diameter	2.0	
Coefficients – 2" PVC	CFM = (Pa/C*L)^(1/n)	
C	0.01146	
n	1.70239	


Design Method
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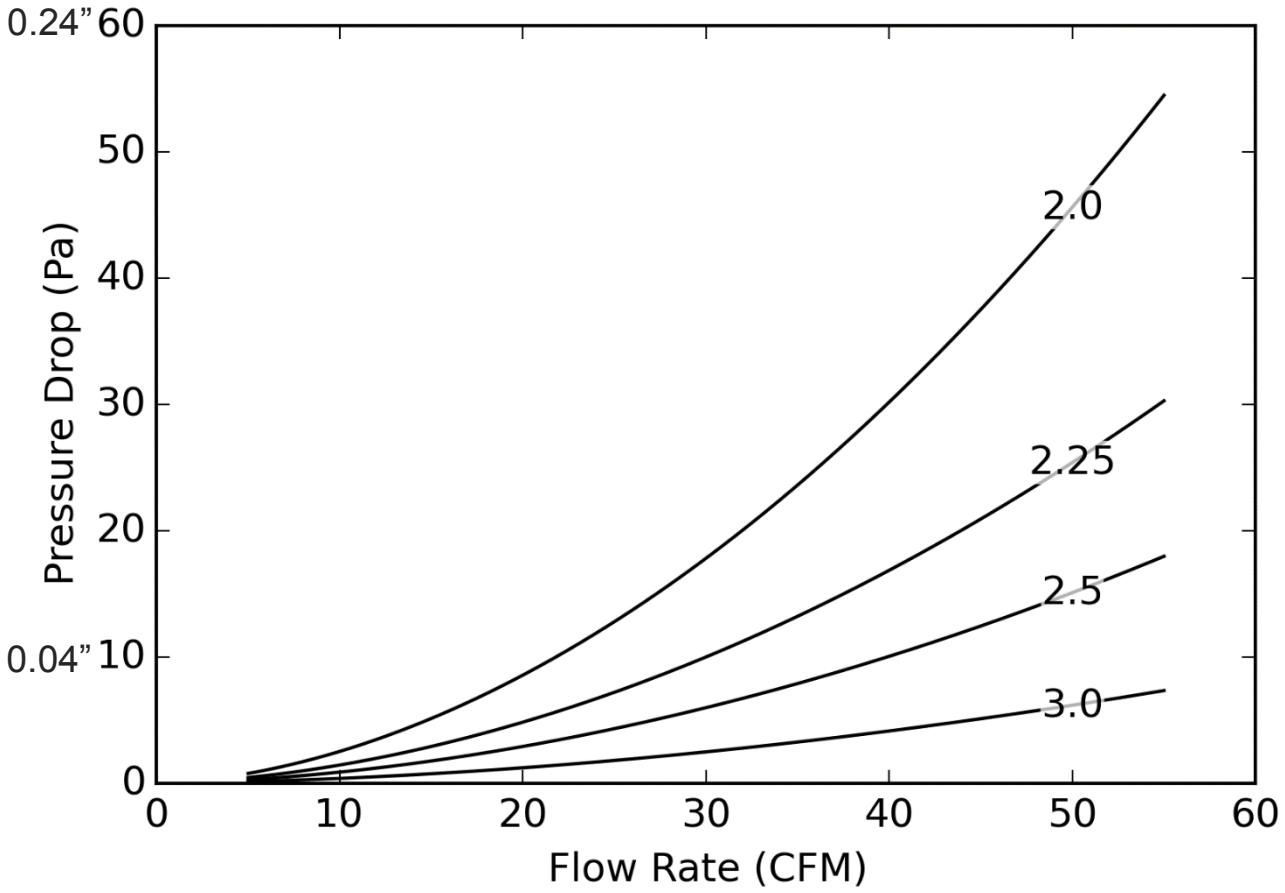
Pressure Testing

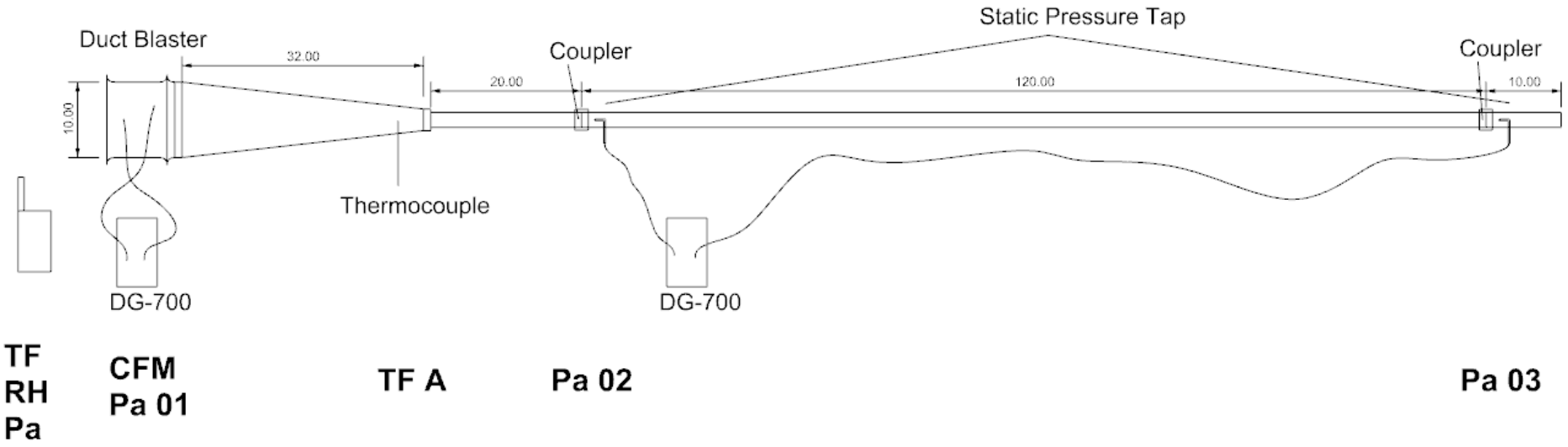
Provide input values for models

Better accuracy than standard assumptions

$$\Delta p = f\frac{\ell\rho(Q)^2}{4\pi^2 r^5}$$



Pressure Testing Setup

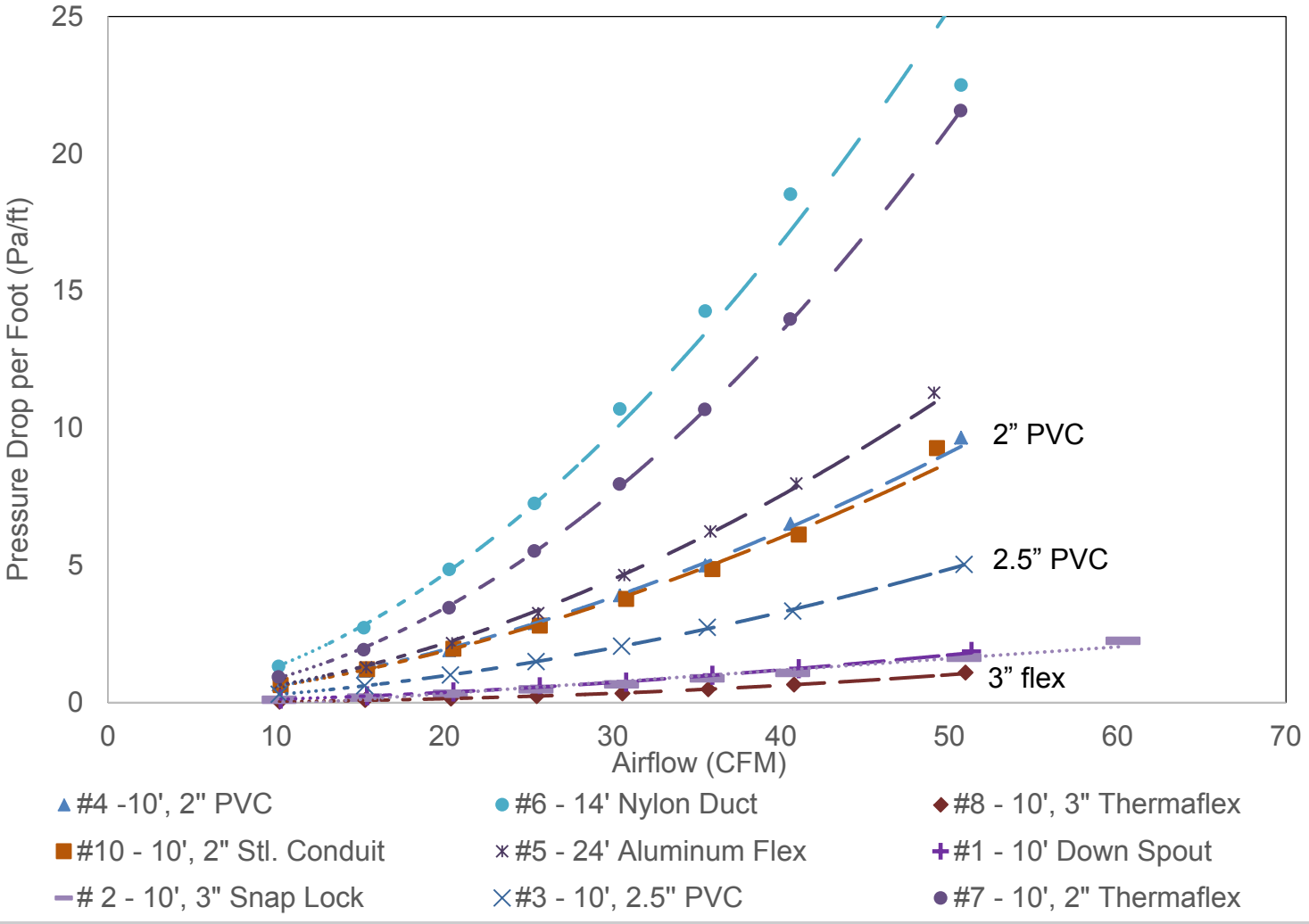


Duct Testing Results

$\Delta P = Cq^n$

Diameter and material are driving factors

3” flex < 3” snap lock



Elbow Testing Results

1 - 90° elbow

E.L. value used in design methodology

Dynamic fitting loss used in simulation

Duct Diameter (in)	Material	Elbow Type	Effective Length (ft) (average of 8 measurements)	Act. Pressure Loss (Pa)
2	PVC	1” Sweep	2.01	9.4
2.5	PVC	Hard 90	4.50	14.8
2	Nylon Fabric	1” Bent Duct	1.69	26
3	Snap Lock	3” Sweep	4.66	5.2
3	Thermaflex	3” Bent Duct	9.32	9.7

Applicability

- Basic assumptions on duct system:
  - 30’ AVG Length
  - 16 Ducts
  - Different materials / diameters
- 40°F Heating ΔT
- 30°F Cooling ΔT
- 0.85 SHR

- 3 Climate zones, 4 Houses, 2 Code levels

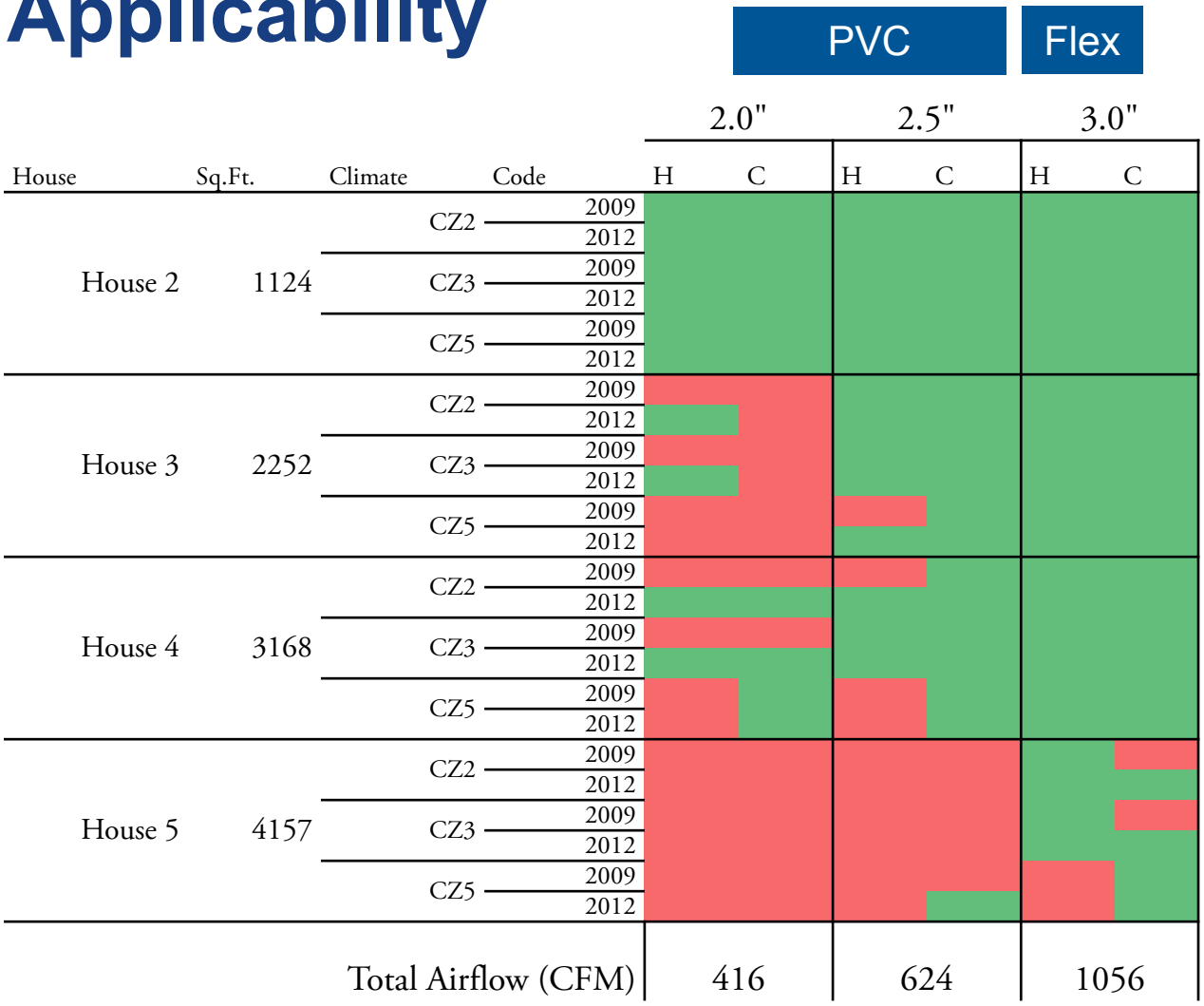
What kinds of homes and climate zones is this applicable?

Limiting factor: Total energy delivered

Applicability

Mid-size ducts – 2.5 – 3.0” work for many homes.

2015 Census: 47 % of new homes 1,800 – 2,999 sq. ft.




Design Method
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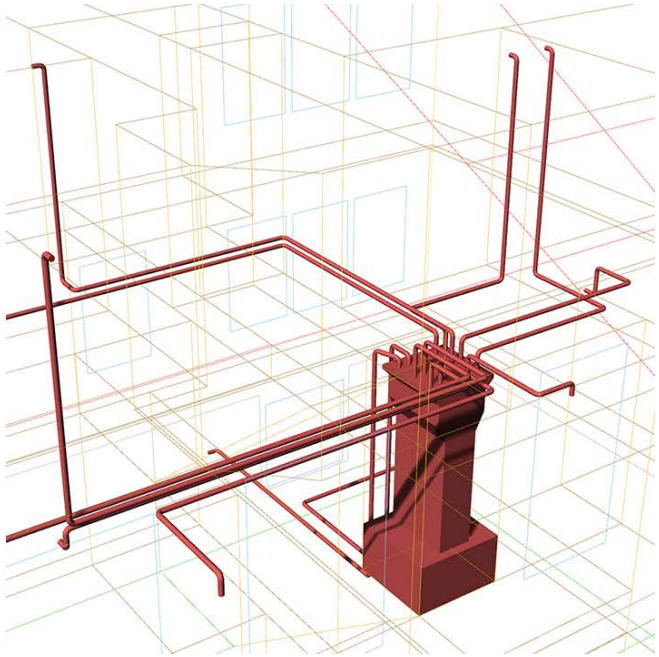
Field Testing: Lab Home

Plug and Play: Test System

12 Ducts – 2.0”

Variable Capacity Air Handler / Modulating Gas Furnace

Measured data used for comparison simulation



	Operation	
	40%	100%
Plenum Pressure (Pa) [in-H2O]	26 [0.10]	80 [0.32]
Total Airflow	139	259

Design Method

Component Testing

House Testing

Simulations

Costs, Codes,

Conclusions

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Simulation

Simulations as an alternative to physical test houses with different air distribution strategies and climate zones.

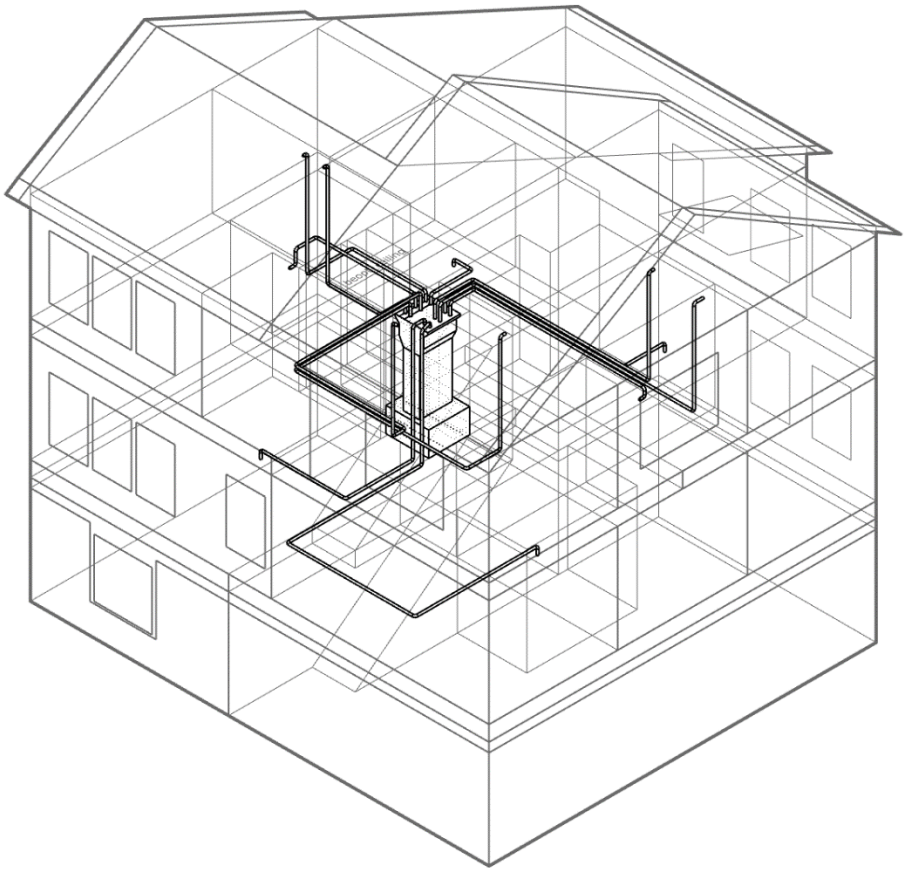
Purpose:

To understand the comfort impact of different air distribution strategies (plug and play vs. trunk and branch)

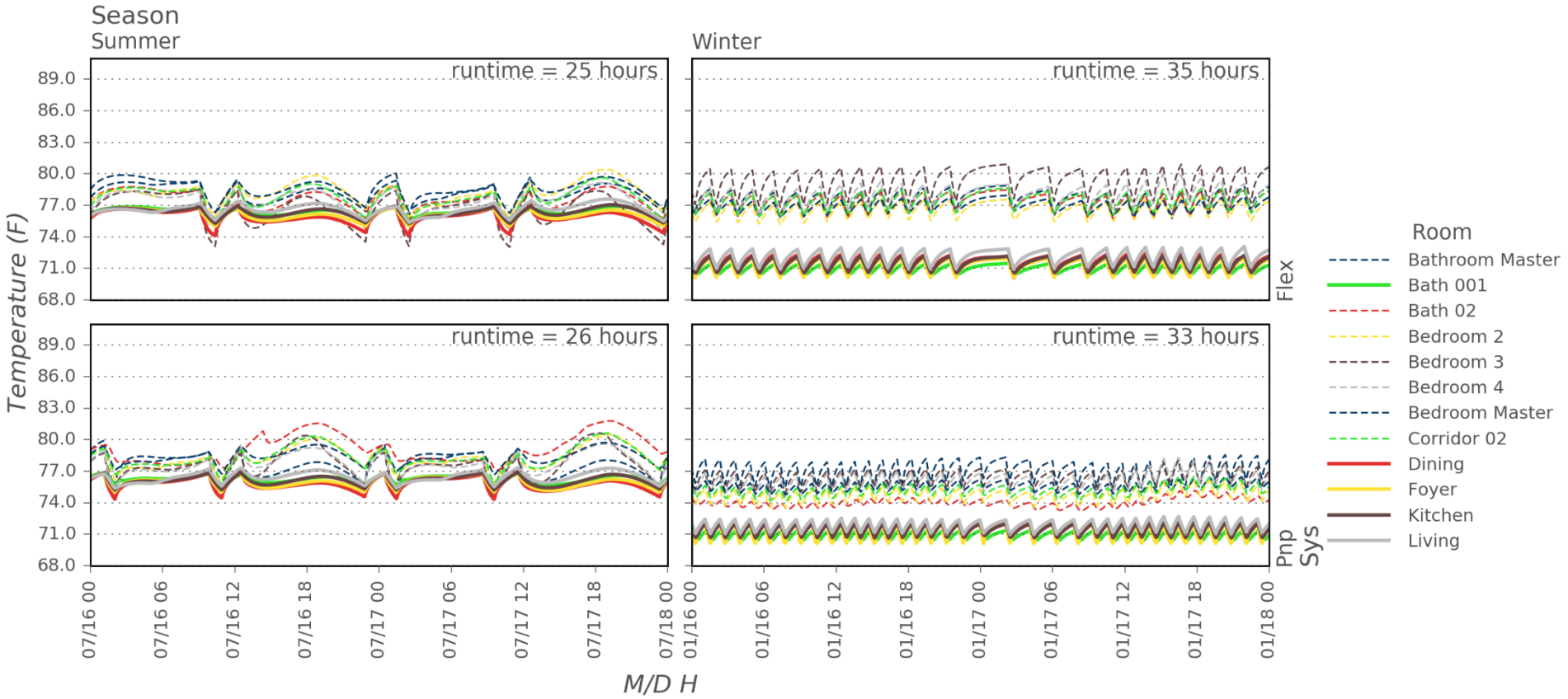
To compare the temperature uniformity (ACCA RS) implications of each design methodology

Simulation

Simulate:
Duct system
Room air mixing
Return air
Air infiltration
Doors
Internal Gains

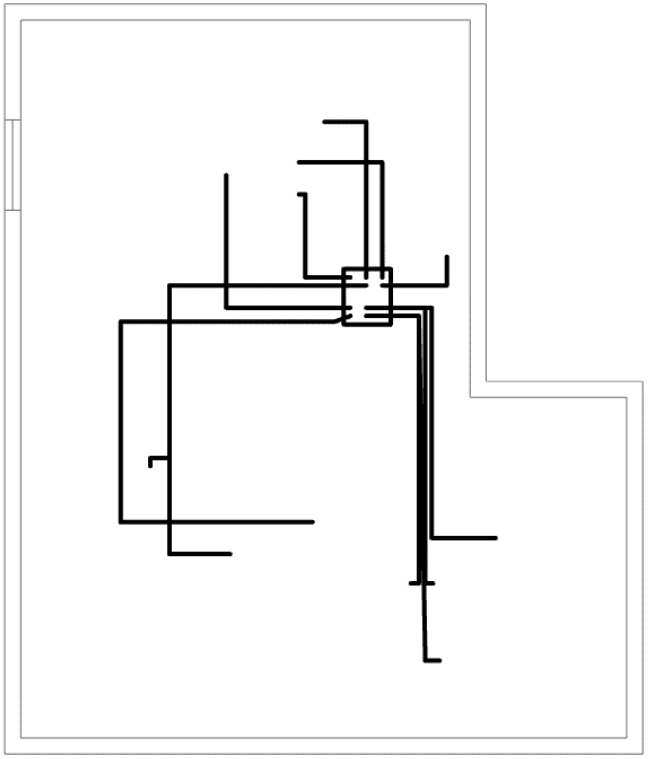


Room Temperatures

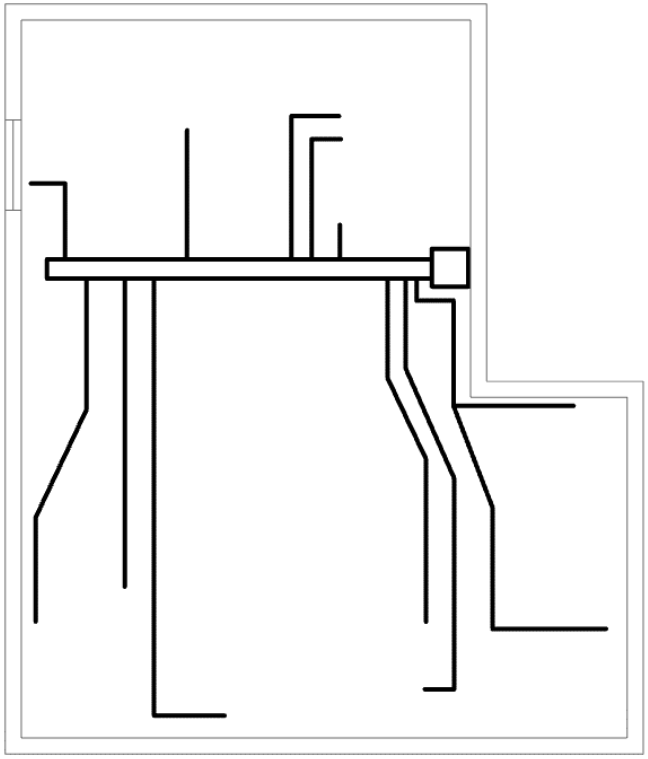


Duct Layouts

Comparing two layouts, to test differences in balancing and those effects on temperature uniformity.



Home Run



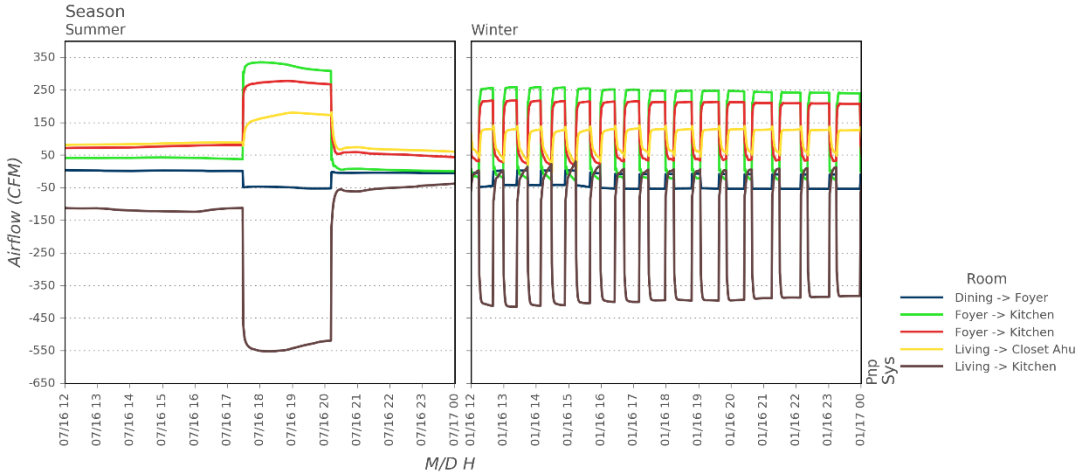
Trunk and Branch

Openings and Infiltration

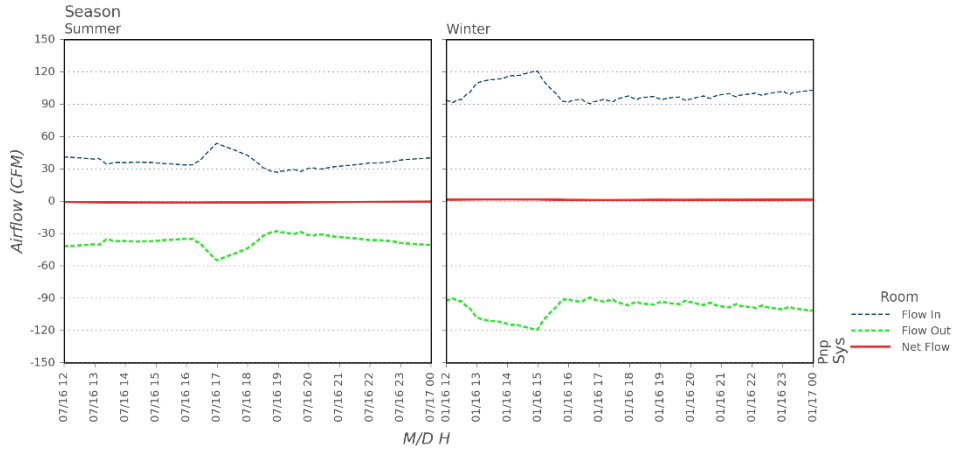
Large openings, interior doors and horizontal openings were included.

Return air pathways were through these openings to central return.

Openings



Infiltration



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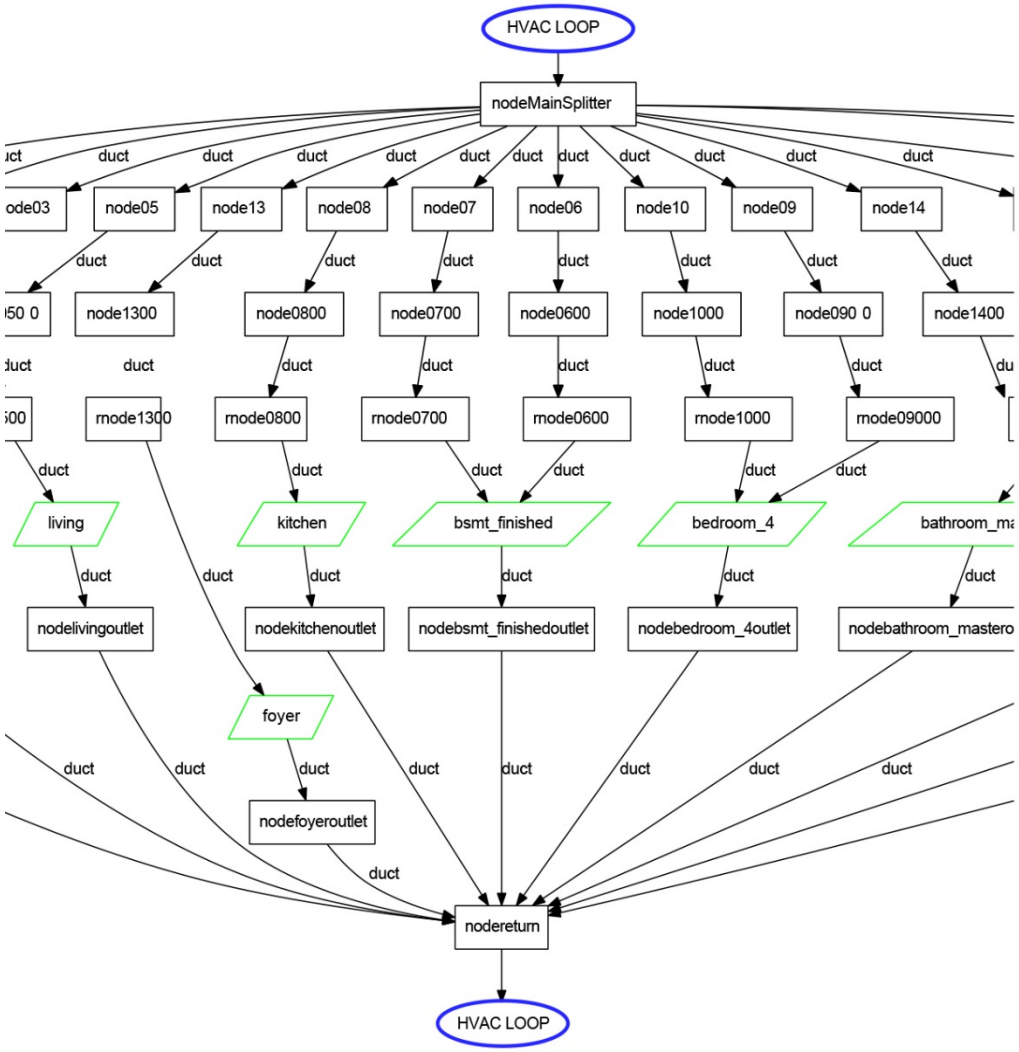
Airflow Network Mechanics

- Openings
- Ducts
- Infiltration

- Utilizing E+ AFN presents challenges

- Small user base

- Little residential precedence



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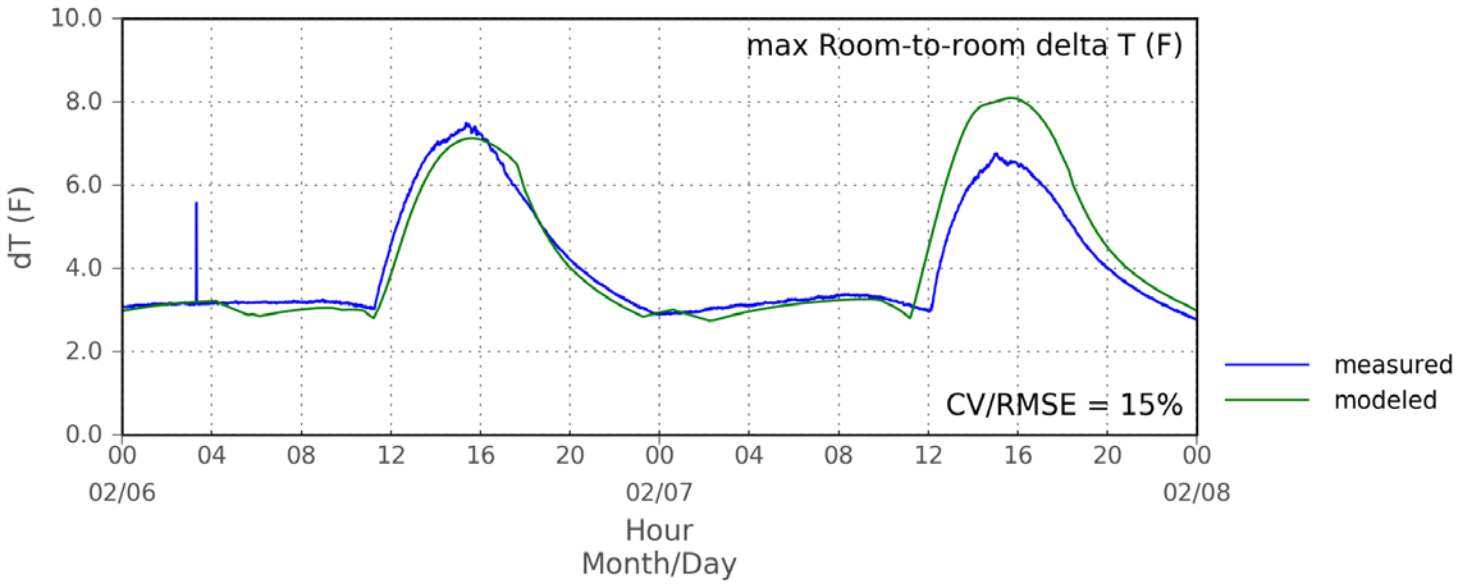
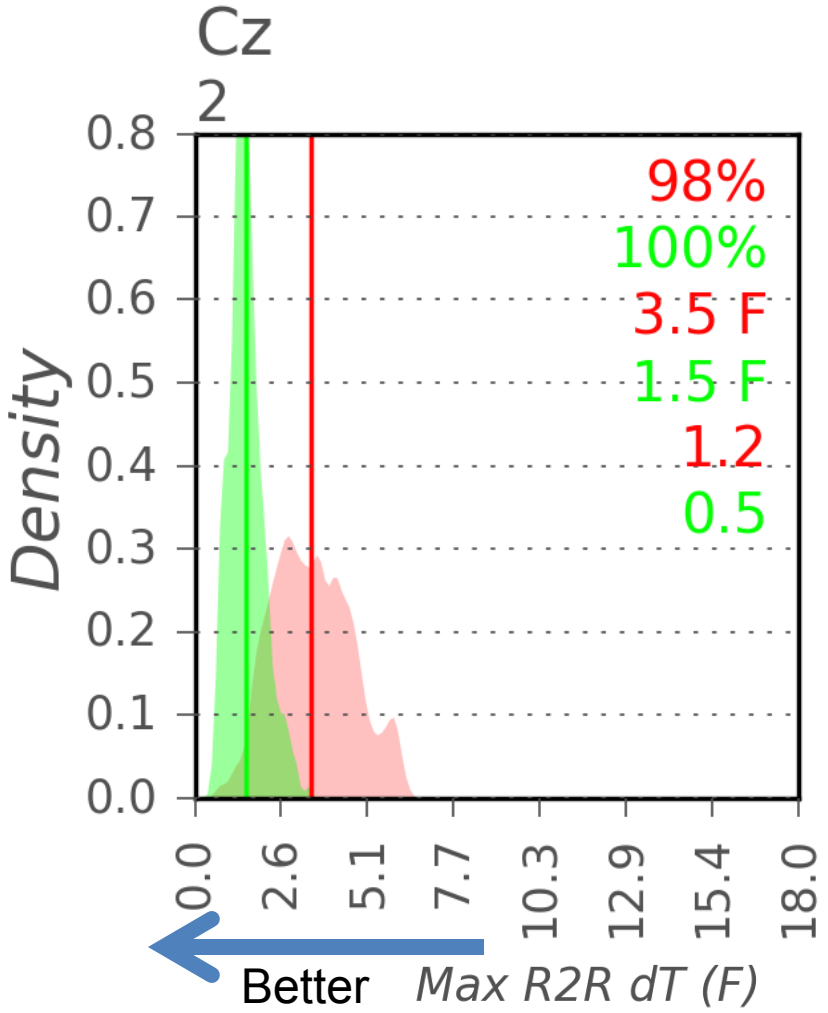
Comparison to Measured Data

Models agree satisfactorily.



Results: Density



% Passing ACCA

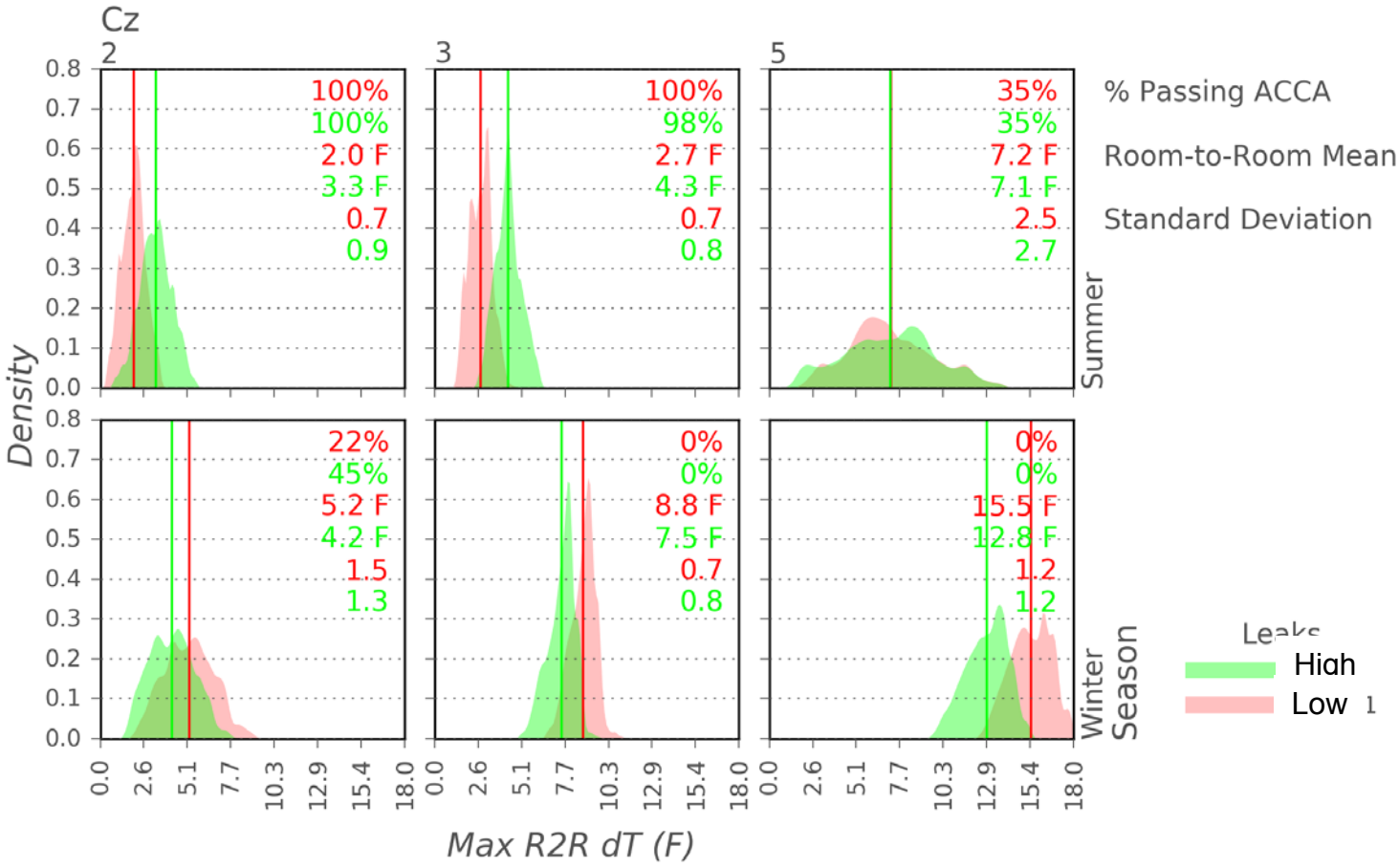
Room-to-Room Mean

Standard Deviation

Duct Leakage – Trunk and Branch

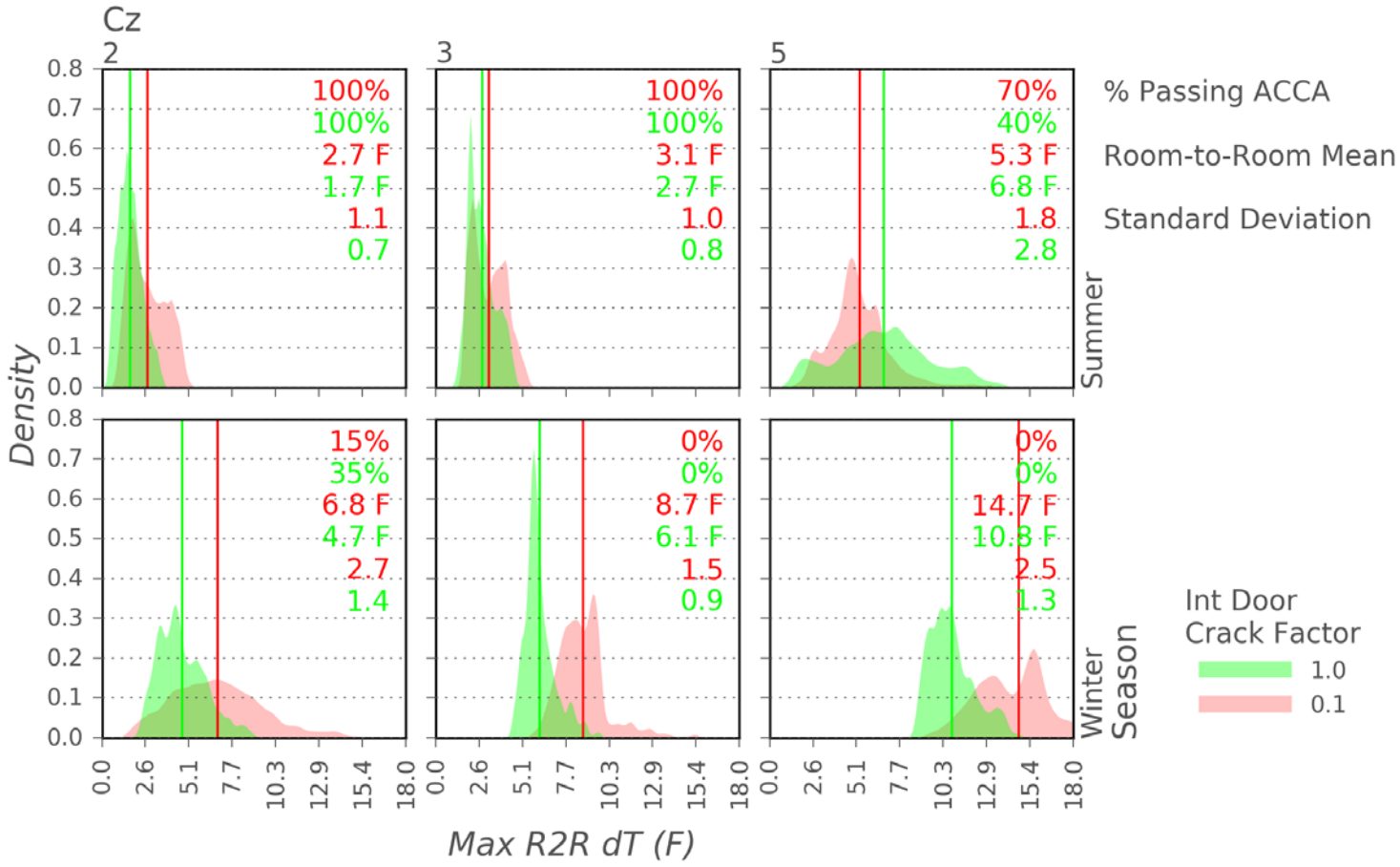
Leaks were simulated at runout connection to plenum.

Leakage effect is dependent on balancing starting point. i.e. if balancing is poor it can help and visa-versa



Interior Doors – Plug and Play

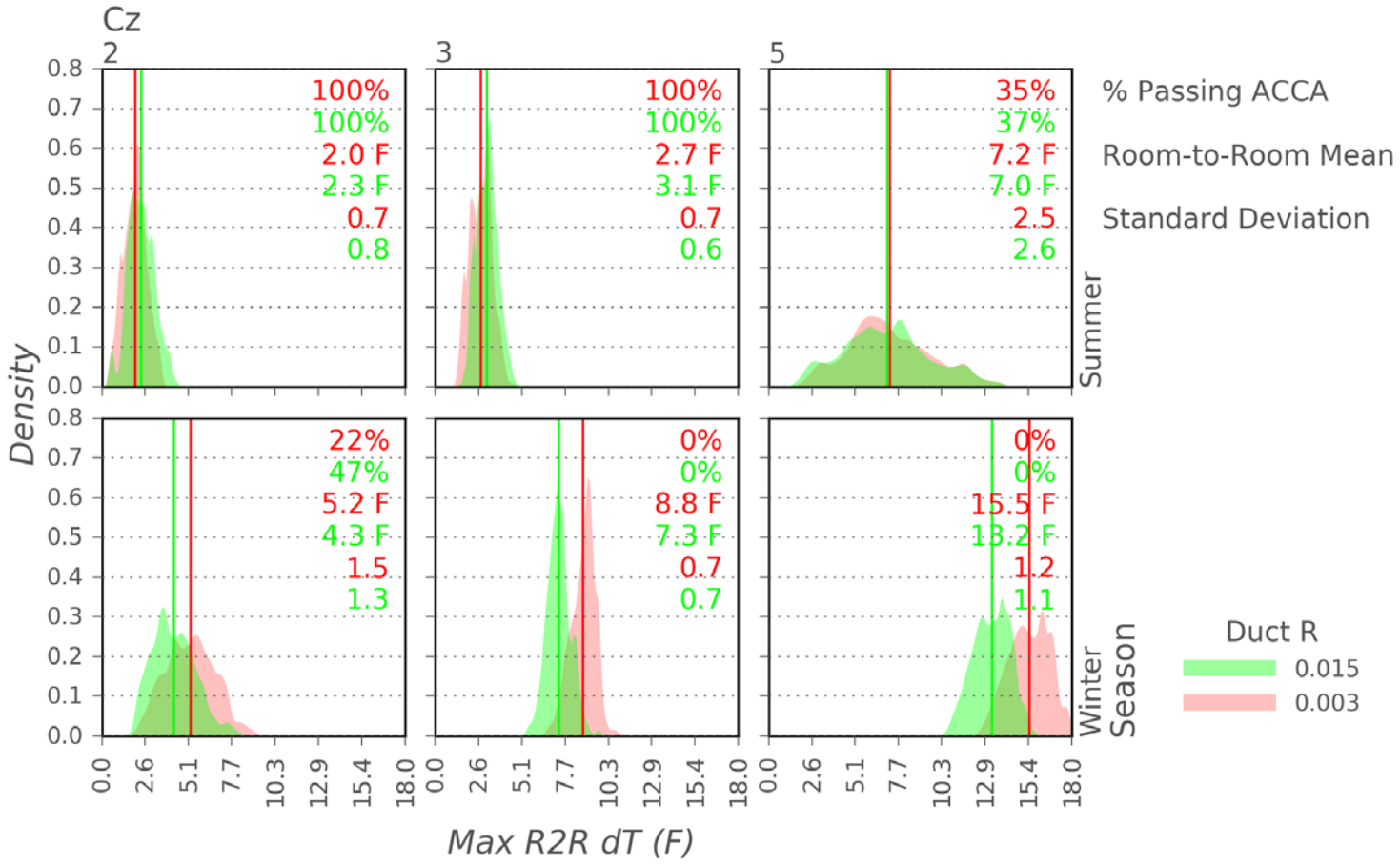
Interior doors have significant impact on temperature uniformity.



Duct Roughness – Trunk and Branch

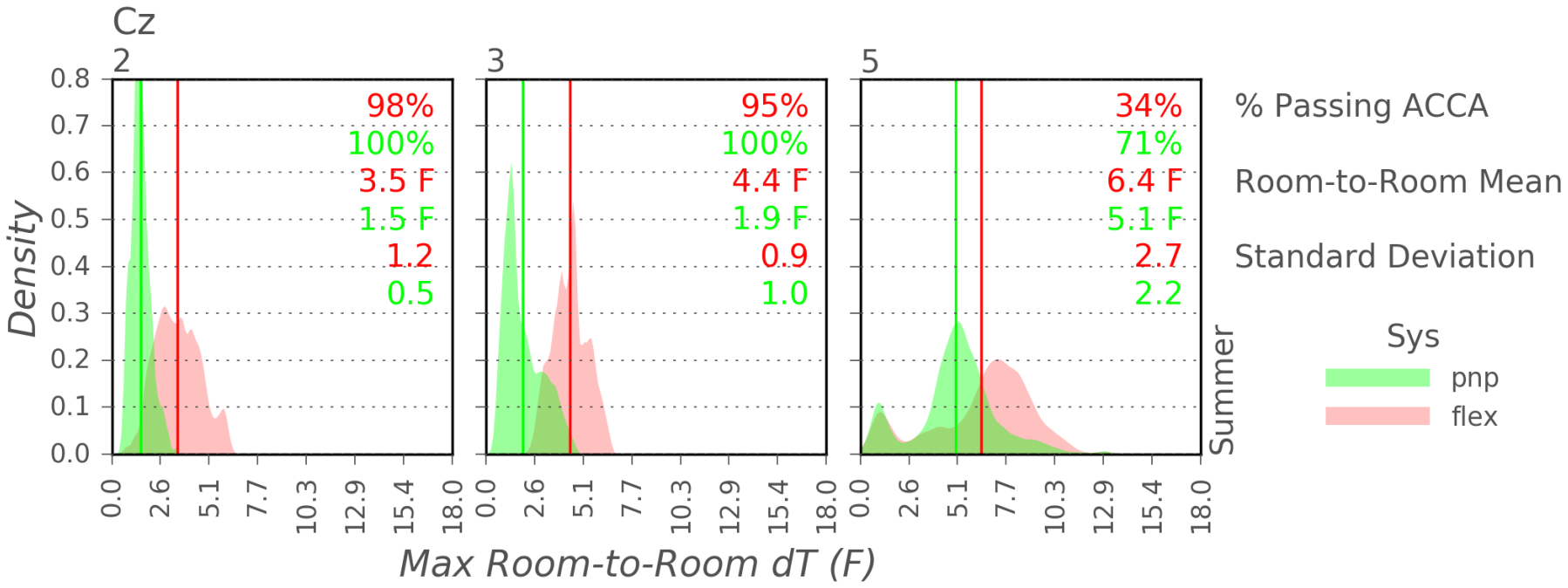
Two uniform roughnesses were simulated to represent flex duct runouts in traditional system.

Higher pressure due to uniform roughness benefits uniformity.

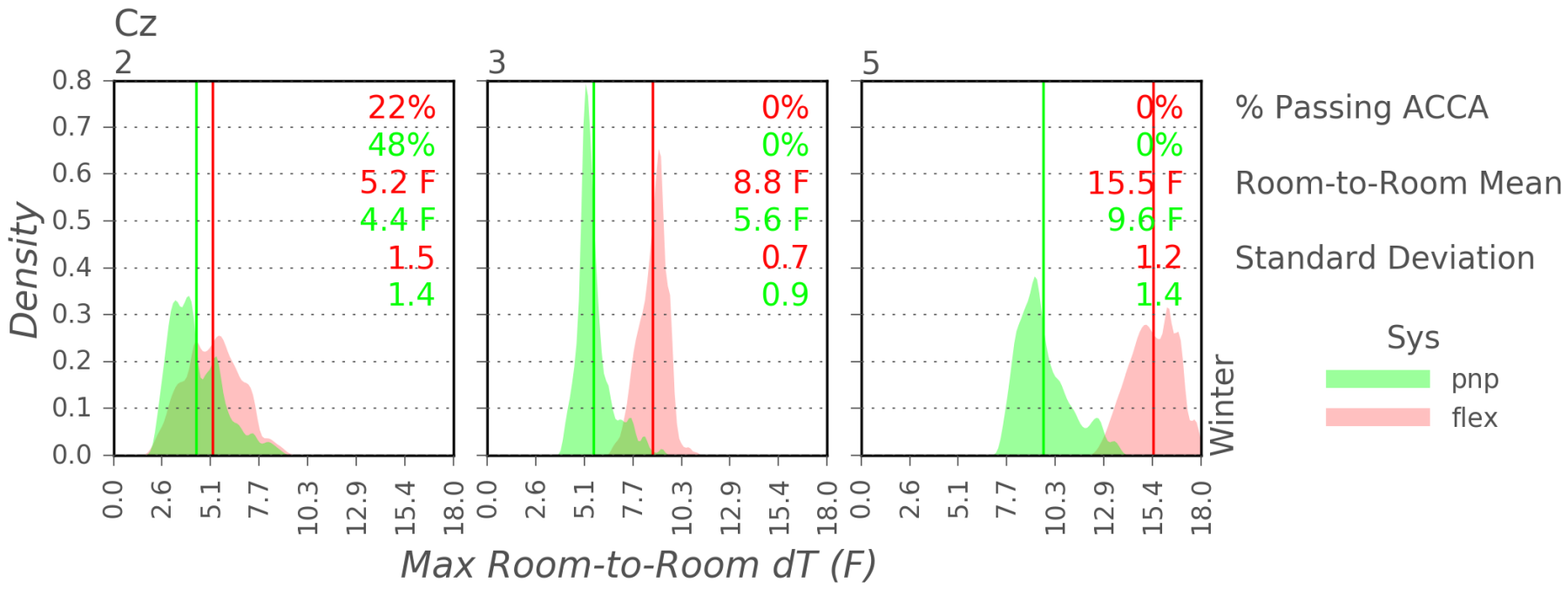


PnP vs Trunk and Branch

PnP vs. Trunk and Branch: Summer



PnP vs. Trunk and Branch: Winter




Design Method
Component Testing
House Testing
Simulations
Costs, Codes,
Conclusions

Time & Motion and Costs

Two-story townhouse, with ductwork in conditioned space

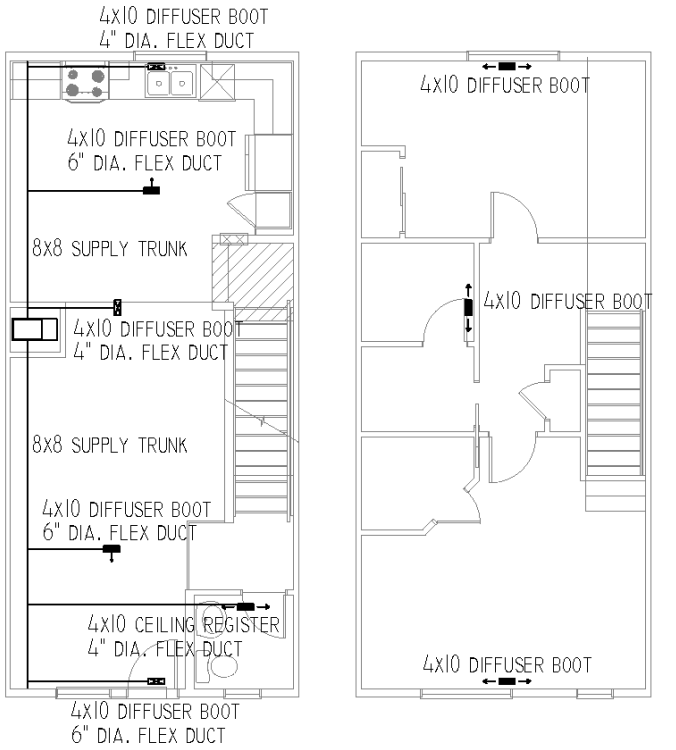
Tradesmen installed each duct system

System Layout

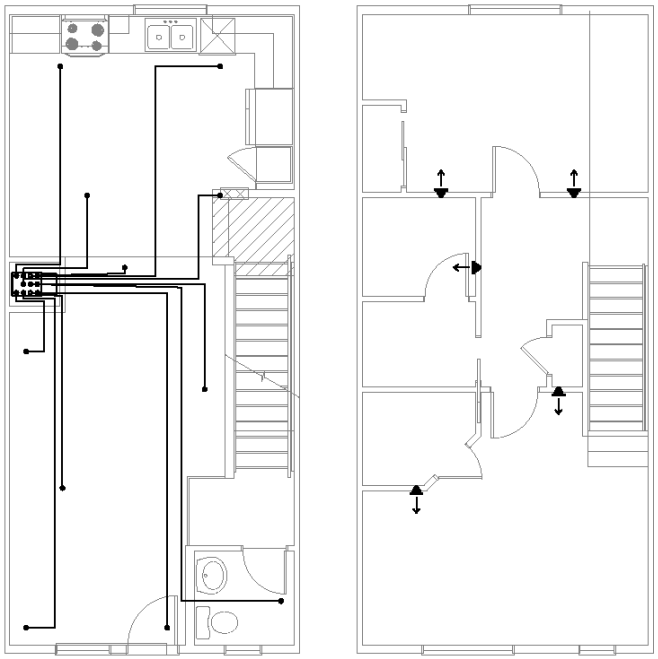
Trunk and branch utilized bulkhead, and floor / ceiling registers.

Plug and play utilized high sidewall registers.

3 Total duct designs



Trunk and Branch



2.0” Plug and Play

Time & Motion and Costs

Trunk and branch installation compared to plug and play using 2.5” and 2.0” ductwork

2.5” ductwork was inflexible and required installation in the bulkhead.

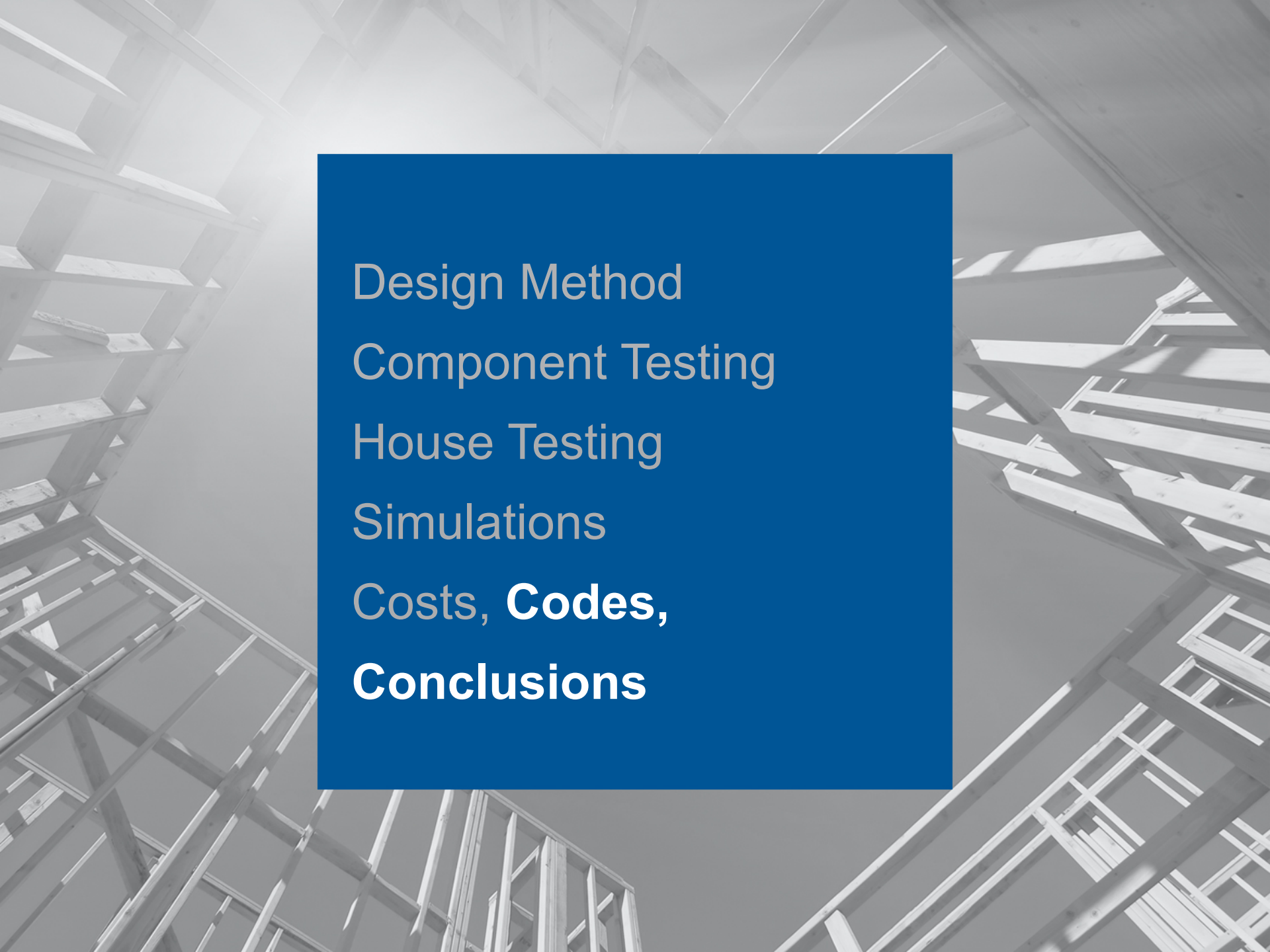
Costs Results

PnP shows labor savings potential.

Elevated cost of 2.5” PVC pipe skewed result.

Schedule 40 pipe used, sch. 10 or 15 would be cheaper.

Duct System	Hours	Labor Cost @ $33.35 hr.	Material Cost	Length of duct	Cost of ductwork system
Traditional	**18** (including 6 hr bulkhead)	**$ 589**	**$ 487**	35’ trunk + 50’ flex	**$ 1,076**
2.5” PVC	**10** (including 6 hr bulkhead)	**$ 330**	**$ 686**	210’	**$ 1,017**
2” PVC	**6**	**$ 195**	**$ 440**	250’	**$ 635**


Design Method
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Codes and Market Engagement

Existing plastic pipes do not meet UL 181.

Interest and excitement from builder community

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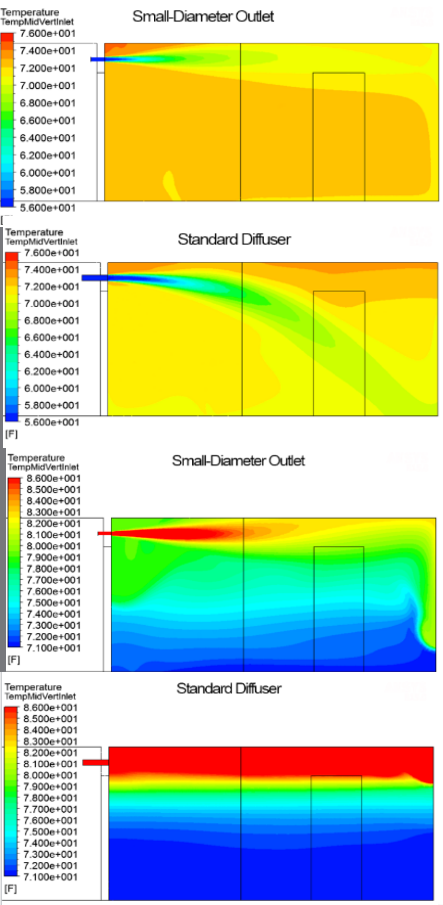

Advantages

- Easier to install in conditioned space
- Quicker and cheaper to design and install
- Fewer unique parts
- Less chance of improper installation, low leakage
- Similar performance to traditional trunk and branch
- Small ducts better matched to low-load homes
- Better throw and mixing with smaller ducts
- Low noise without diffuser-type grille

Challenges

- Greater need to integrate duct layout with framing to ensure compact duct layout
- Codes still present an issue with rigid ductwork

Next Steps

- Commercialize technology
- Demonstrate performance in occupied homes
- Continue to pursue code acceptance for commodity plastic ducts

Conclusions

Performance

- 2.5” - 3.0” Ducts could service a wide range of newly-constructed homes in the U.S.
- Comfort (thermal uniformity) is similar to or better than conventional trunk and branch ducts.

Cost

- Reduced installation time, and significant potential for material cost reductions

Design

- Initial work shows promise for simplified design tool.

Market

- Excitement for innovation in air delivery systems

Contact

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