NIST Capabilities/Program Opportunities for Manufactured Housing
…what's up in Gaithersburg

Andrew Persily, andyp@nist.gov, 301 975-6418
Engineering Laboratory
National Institute of Standards and Technology
Gaithersburg, Maryland

Manufactured Housing Consensus Committee
October 27, 2010

OUTLINE

- **NIST Indoor Air Quality and Ventilation Group**
- **Modeling study of infiltration and ventilation in manufactured homes**
- **Study of airtightening retrofits**
- **Other questions and potential answers**

NIST IAQ and Ventilation Group

- Airflow and IAQ model development; Ventilation and indoor pollutant measurements; Energy and IAQ impacts of IAQ controls
- Five engineers; students and guest researchers 50 % NIST funded; 50 % from other agencies
- ASHRAE and ASTM activities
  - Chair of ASHRAE Standard 62.2 and members of Environmental Health Committee
  - ASTM Subcommittee on Indoor Air Quality
  - ASTM Subcommittee on Infiltration and Ventilation

IAQ & Ventilation Group Facilities

Test House

Environmental

IAQ & Ventilation Group Projects

Airborne nanoparticles from residential sources (NIST)

Performance of filtration and air cleaning systems (NIST)

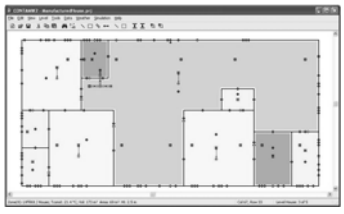
CO Emissions from Emergency Generators (CPSC/CDC)

VOC emissions reference standard (NIST)

CONTAM (IAQ model) development & application (NIST)

Suite of homes for ventilation and IAQ analysis (HUD)

A Modeling Study of Ventilation in Manufactured Houses



Persily, Martin. 2000. Report No. NISTIR 6455. Prepared for HUD Office of Policy Development and Research

Modeling Study: Background

HUD MHCSS Requirements

Minimum air change rate of 0.35 h^{-1}

Mechanical or passive system to provide 0.1 h^{-1} (assumes infiltration rate of 0.25 h^{-1})

Variety of systems being used to meet standard

Outdoor air intake on forced-air furnace return

Whole house exhaust fan with or without inlet vents

Modeling Study: Questions

Validity of 0.25 h-1 assumption for infiltration

Ventilation rates, air distribution and energy use of systems used to meet MHCSS :

Outdoor air inlet on furnace return

Whole house exhaust with passive inlets

Whole house exhaust without passive inlets

Modeling Study: Simulation Approach

CONTAM multizone airflow model

Exterior envelope leakage, interior partitions, forced-air distribution and duct leakage, exhaust fan operation, and outdoor weather

Steady-state airflow for different systems

Annual simulations in Miami (hot/humid), Albany (cold/mixed), Seattle (temperate)

Modeling Study: Results (Albany)

Simulation conditions	Mean air change rate (h^{-1})	% of hours < 0. 35 h^{-1}	Effective air change rate (h^{-1})
Envelope leakage and scheduled exhaust fans	0.27	77	0.17
Forced-air inlet; operating on outside temperature	0.37	46	0.19
Forced-air inlet operating during occupancy	0.59	18	0.34
Passive inlets: whole house exhaust on limited schedule	0.41	42	0.24
Passive inlets: whole house exhaust on during occupancy	0.50	29	0.34

Modeling Study: Energy Use (Albany)

Simulation Conditions	Annual Energy Use MJ (kWh) Heating, Cooling and Fans
No mechanical ventilation, infiltration and local exhaust	18459 (5128)
Forced-air inlet, controlled by out	20140 (5595)
Forced-air inlet operating during occupancy	31339 (8706)
Passive inlets; whole house exhaust on limited schedule	21217 (5894)
Passive inlets: whole house exhaust during occupancy	24646 (6846)
Constant air change rate of 0.35 h^{-1}	14970 (4159)

Modeling Study: Conclusions

0.25 h^{-1} assumption for infiltration

Ignores weather; < 0.25 h^{-1} for much of the year

Outdoor air inlet on furnace return

Provides sufficient ventilation and good distribution, but impact depends on operating strategy; potential for both under- and over-ventilation

Whole house exhaust fan with passive inlet vents

Sufficient ventilation and good distribution, but depends on operation; potential for under- and over-ventilation; makes more sense in tight buildings

Modeling Study: Recommendations

Modify infiltration assumption in standard to account for weather-induced variation

Standards need to address operation of mechanical ventilation systems

"Optimize" by tightening ducts and building envelope, then deal with systems

Investigate pollutant impacts of ventilation

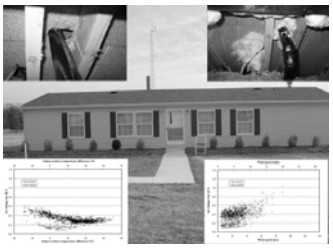
Verify findings through field studies

NIST RESEARCH HOUSE

Delivery and installation, January 2002




Impacts of Airtightening Retrofits on Ventilation and Energy Use in a Manufactured Home



Nabinger, Persily, Dols. 2010. NIST Technical Note No. 1673.

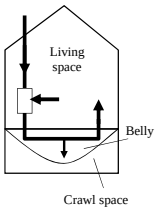
Retrofit Study: Background

- Manufactured homes: about 6 % of U.S. residences
- U.S. manufactured homes built to HUD MHCSS
  - Requires mechanical ventilation
- Technical issues regarding ventilation
  - Infiltration impacts
  - Duct leakage
  - System operation
  - Energy and IAQ impacts

Retrofit Study: Objectives

- Previous modeling study of MH ventilation for HUD
  - Ventilation system operation schedule is key
  - Infiltration has significant impacts on air change rate (duct leakage into house belly)
- Previous field studies
  - Leaky ducts and envelopes common
  - Tight construction can be achieved
- "Typical" (not very tight) manufactured home instrumented for ventilation and IAQ research
- **Study objective: Determine impacts of airtightening retrofits on leakage, ventilation and energy**

Test House



- Located in Gaithersburg, MD
- Three bedrooms, floor area 140 m^2, vented crawlspace
- Forced-air heating/cooling
  - Ductwork in insulated belly
  - Rooftop outdoor air intake connected to return
- Instrumented for temp, RH, pressure, air change, energy
- More info in Nabinger and Persily, 2007, NISTIR 7478

Retrofits

- Floor penetrations, e.g. plumbing
- Duct leakage
- Housewrap (replaced siding)

Mastic around floor registers

"Oversized" holes: Before and after

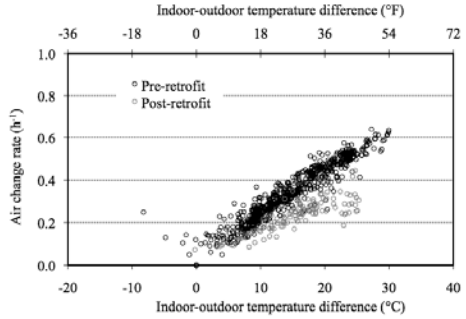
Results

	Before	After
Sum of supply vents	729 cfm	953 cfm
Supply duct leakage	284 cfm	~ 50 cfm
Outdoor air intake (MHCSS 53 cfm)	16 cfm	28 cfm
Kitchen exhaust (MHCSS 100 cfm)	57 cfm	--
Toilet exhaust (MHCSS 50 cfm)	~15 cfm	--

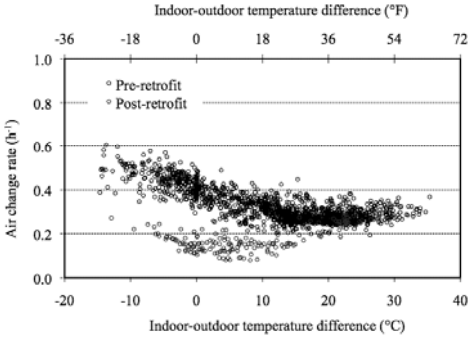
Results

	Before	After
Air change rate at 50 Pa	11.8 h^{-1}	9.0 h^{-1}
ELA at 4 Pa	728 cm^2	555 cm^2
Duct leakage ELA at 25 Pa	320 cm^2	58 cm^2
ELA - house to crawl space	230 cm^2	90 cm^2

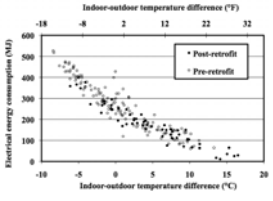
Results: Fan-off infiltration rates



Results: Fan-on infiltration rates

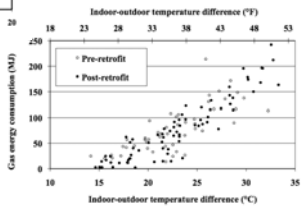


Results: Energy

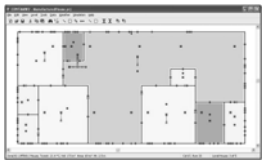


COOLING: 12 % lower

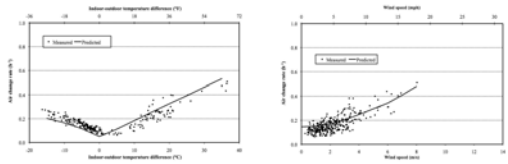
HEATING: 9 % lower



Model Predictions of Airflow Rates



CONTAM model of manufactured house



CONTAM predictions vs. measurements, post-retrofit

Retrofit Study: Conclusions

- "Standard" manufactured house: leaky envelope & ducts
- Retrofits improved airtightness and lowered energy use
- More effective during construction than retrofit
- Cases of both over- and under-ventilation, even after retrofit; mechanical ventilation control
- Able to predict air change rates with multizone modeling

Other Thoughts

- MH airflows result from interaction of envelope, systems, belly, duct leakage, … Must understand and address them all
- Infiltration is not a good way to ventilation; leaky houses can be underventilated
- ASHRAE Standard 62.2 applies to manufactured homes
- Installed ventilation capacity vs. operation
- Need to consider indoor contaminants: measurement and modeling studies
- Modeling is a powerful tool to understand these issues