

Duct Leakage Repeatability Testing

Dr. Iain Walker, LBNL

Max Sherman, LBNL

Paul Francisco, University of Illinois



Background

- Test repeatability an important issue for codes, standards, energy programs, etc.
 - Different evaluators should get roughly the same answer
 - Impacts uncertainty in program efficacy: if target is 6% but what if repeatability is +/- 10%???
- Are some test methods significantly better or worse than others?
- Identify sources of error

Test Plan

- Evaluate the three test methods from ASTM E1554:
 - Pressurization total
 - Pressurization to outside
 - DeltaQ (note supply and return added to compare to pressurization tests)
- Building America teams tested ten homes in three geographical locations (30 homes total):
 - Champaign, IL by PARR
 - Minneapolis, MN by CEE
 - Atlanta, GA by Southface

Test Plan

- 3 days per home
 - One day dedicated to each test method – roughly 10 repeats
 - Test equipment dismantled for every test
 - Calculate mean leakage
 - Calculate standard deviation – estimate of repeatability
- Measure Envelope Leakage
- Characterize homes: floor area, duct location, system type
- Measure total system air flow – used to determine fractional leakage
- Measure wind speed and indoor/outdoor temperatures

Previous Studies – DeltaQ Focus

Field Studies Only

- Walker & Dickerhoff (2006 & 2008)
 - Repeated DeltaQ testing 5 times in four homes: RMS was +/- 5 to 7 cfm
 - Rule of thumb repeatability = 1% Q50
 - 2000 ft² 5 ACH50 home = +/-14 cfm
- Dickerhoff & Walker (2008)
 - Repeated DeltaQ testing in seven homes – similar rule of thumb
- Francisco (2009)
 - DeltaQ in 15 homes, minimum of 5 repeats – half of results within about 30% of 1% Q50 rule of thumb
- Walker et al. (1998)
 - Repeated Pressurization Total testing two to four times in nine new homes: +/- 16 cfm

House and System Summary

	Envelope Leakage, Q50 (cfm)				Blower Flow (cfm)				Avg. Floor Area (sq.ft.)	Avg. Wind Speed (mph)
	Average	s.d.	Min.	Max.	Average	s.d.	Min.	Max.		
PARR	2002	921	940	3445	1030	771	380	2942	1364	2
CEE	1936	587	945	2911	891	205	704	1424	2465	10
Southface	2879	1181	1219	4456	706	281	296	1128	1658	1
All	2272	1022	940	4456	876	490	296	2942	1829	4

	Envelope Leakage, ACH50			
	Average	s.d.	Min.	Max.
PARR	12.3	6.1	4.2	21
CEE	6.2	2.1	3.6	10.9
Southface	14.1	5.8	8.1	23.9
All	11	6	3.6	23.9

- Large range of home, system flow, envelope leakage
- Envelopes are much leakier (four times!) than new homes
- Most systems in basements/crawlspaces
- Wind is tricky to measure?

Duct Leakage Summary, cfm

	DeltaQ	Delta	Ptot	Ptot	Pout	Pout
	avg.	s.d.	avg.	s.d.	avg.	s.d.
PARR	190	32	666	30	492	18
CEE	39	36	1001	8	87	2
Southface	220	46	1075	92	442	15
All	150	38	914	43	340	12

?

- DeltaQ lowest leakage
- Pressurization to outside less than pressurization total
- Some pressurization results problematic – i.e., very high

Duct Leakage Summary, % of blower flow

?	DeltaQ?	DeltaQ?	Ptot?	Ptot?	Pout?	Pout?
	avg.?	s.d.?	avg.?	s.d.?	avg.?	s.d.?
PARR?	21?	3?	72?	3?	56?	2?
CEE?	4?	4?	110?	1?	9?	0?
Southface?	45?	9?	181?	15?	80?	2?
All?	23?	5?	121?	6?	48?	1?

Pressurization to outside clearly lowest s.d.

What's going on with pressurization?

- 7/30 could not reach 25 Pa (total), 1 home to outside
 - Extrapolated to 25 assuming pressure exponent of 0.5
- Systems using building cavities as ducts in basements and crawlspaces – lots of big holes normally at low pressure c/w 25 Pa test pressure

One DeltaQ house gave -1 cfm result. For a leaky house the uncertainty is greater than the measured leakage for very tight ducts.

Low Leakage Test Results

	DeltaQ	DeltaQ	Ptot	Ptot	Pout	Pout
	avg.	s.d.	avg.	s.d.	avg.	s.d.
cfm	29	28	832	10	115	3
%flow	3	3	91	1	14	0.3

?

For 12 homes with DeltaQ test results < 6% of system flow:

- Lower s.d. for all tests
- Pout particularly good repeatability

BUT.....

- Ptot huge overpredictions
- Pout more reasonable

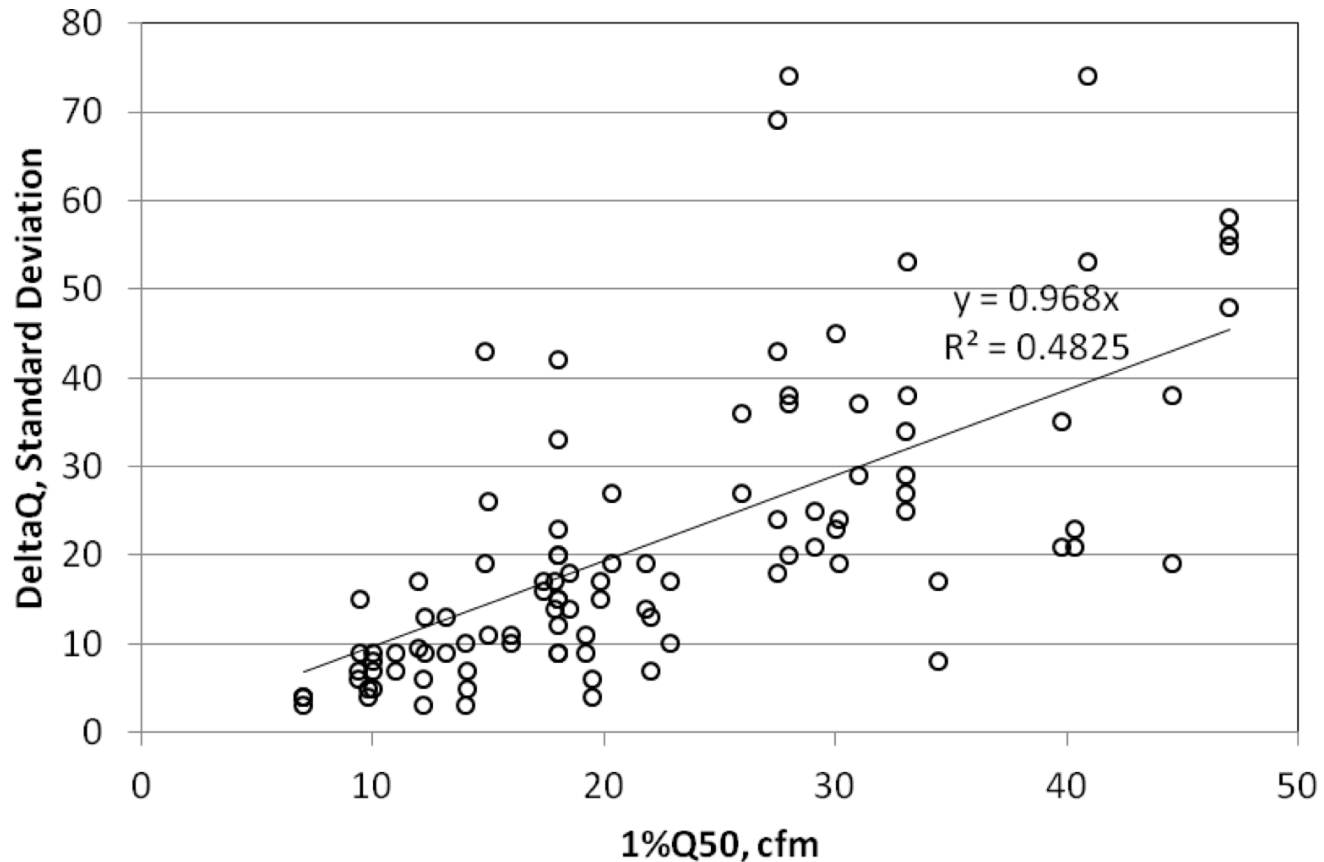
Time to perform tests, Minutes

DQ, [?]		Ptot, [?]			
first [?]	DQ [?]	first [?]	Ptot [?]	Pout, [?]	Pout [?]
avg. [?]	avg. [?]	avg. [?]	avg. [??]	first [?]	avg. [?]
54 [?]	25 [?]	68 [?]	31 [?]	65 [?]	32 [?]

[?]

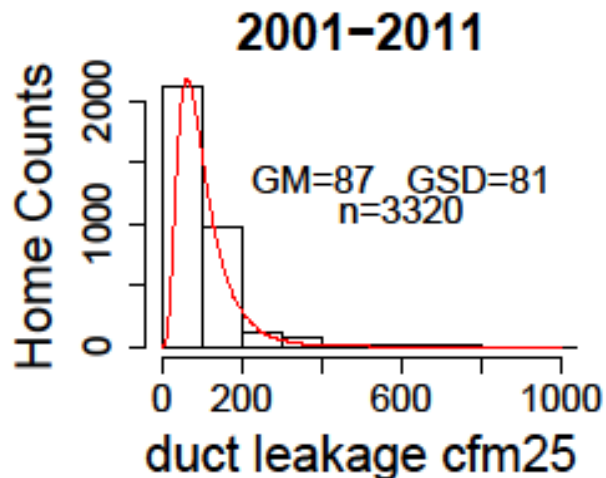
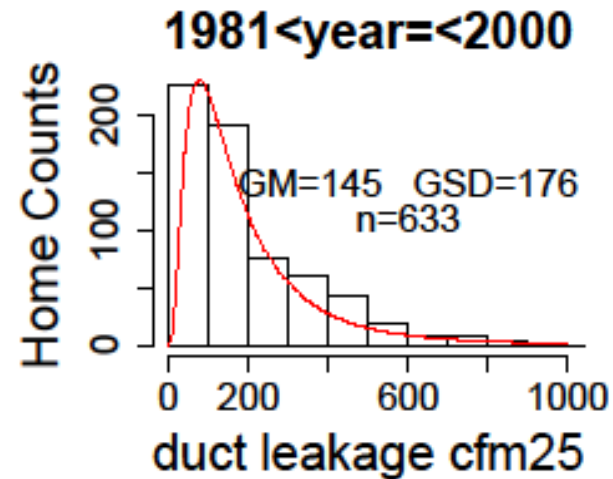
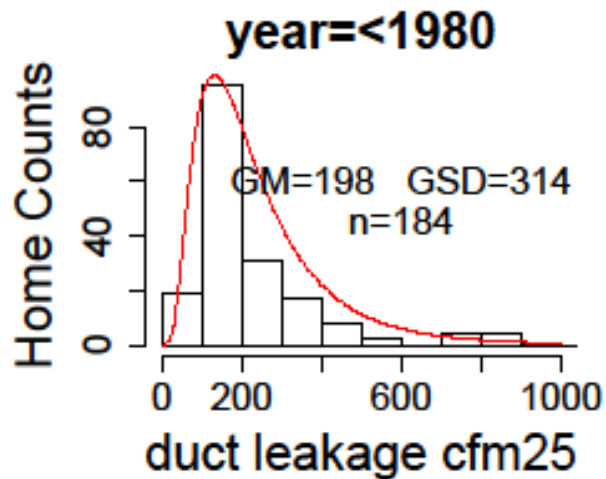
- First test much longer... need to find all registers, find power outlets, find a good location for pressure tubing, find and check doors, windows, water heaters, fire places, furnaces, ducts etc.
- Testing for leakage to outside no more time than a total leakage test & its *not* test order
- House to house variability in times for first test is about 20 minutes for all tests – some houses are easier than others
- DeltaQ fastest – likely due to not having to locate and seal all registers

A Rule of Thumb for DeltaQ: 1% Q50

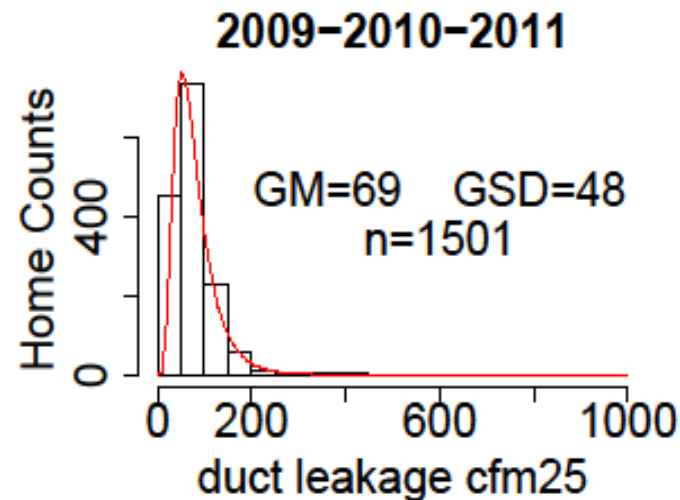
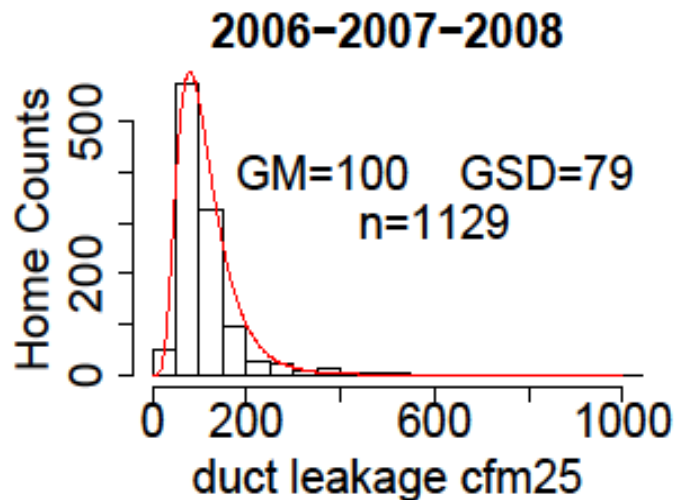
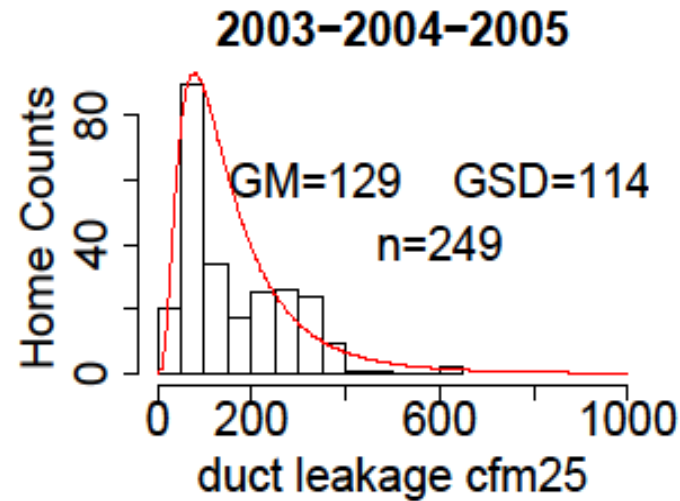
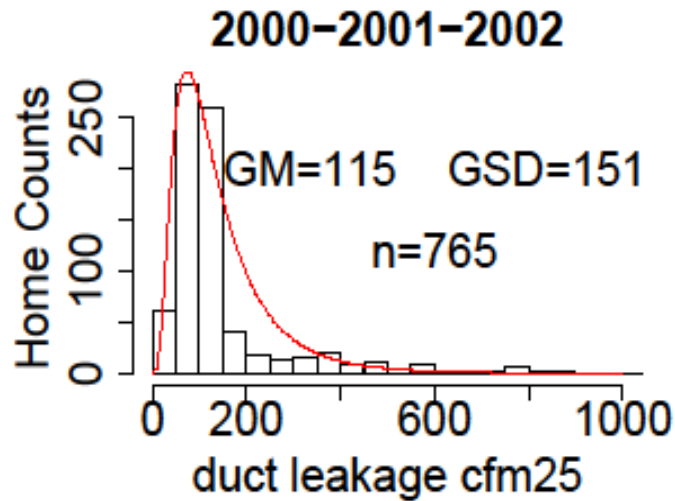


Mean difference between rule of thumb and measured results is 1 cfm
RMS difference is 11 cfm

Duct Systems Getting Tighter



Duct Systems Getting Tighter



Do the tests agree on tight systems?

- What is “tight”?
- Most codes/standards/programs: 6% of total system flow (or roughly equivalent cfm/floor area)
- Pressurization to outside & DeltaQ pretty much agree: five homes of which DeltaQ matched four times
- DeltaQ has an additional 8 homes identified as low leakage
- Pressurization total did not identify any tight systems (note that many thousands of homes have been tested to meet this leakage level using pressurization in NEW construction where ducts are much tighter)

Repeatability Observations

- Repeatability is OK for all three tests
- Pressurization to outside has best repeatability: +/- 1% of blower flow
- DeltaQ and total pressurization about the same at +/- 6% of blower flow
- Repeatability much better for low leakage ducts
- These were older homes with leaky ducts and envelopes – we expect better repeatability in newer homes
 - DeltaQ in particular – repeatability scales with envelope leakage
- Compare to test accuracy from lab test: roughly 5% of blower flow for pressurization and 2.5% for DeltaQ

Repeatability Observations

- With 7 of 30 homes not able to reach 25 Pa and giving very high results for pressurization care must be taken with this approach
 - Basement/crawlspace systems + building cavities
- DeltaQ can sometimes give small negative results (~1% of blower flow) at low leakage levels
- Mean wind speed did not have an impact – much windier site did not see greater repeatability uncertainty
 - this has been seen in previous studies – it is large sustained gusts that lead to problems

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