- Air Barrier Workshop
- 9-9:45 Whole Building Testing
- This presentation will provide some experience gained from the whole building testing of dozens of diverse large buildings, and summarize the results of hundreds of tests from specific geographic areas. Specific examples of challenges met, and future obstacles to be overcome, will discussed. The airtightness data will be examined for trends and recommendations for future practise and research made.
- The audience is very knowledgeable but somewhat lacking in a full understanding of whole building testing. The goal is for the attendees to fully understand that the industry can test whole building right now.

Airtightness testing

Dr John Straube, P.Eng.

Associate Professor, University of Waterloo

Principal, RDH Building Science

History of Airtightness

- Implicit for thousands of years
- Explicitly provide
  - Building paper

and will not be affected by dampness. Being submitted during the process of manufacture to a pressure of hundreds of tons, its fibers are so compressed into a solid body that it is not only absolutely air-tight, but

peting. Finally, an estimate of cost, showing that a house of 16 by 22 feet, and 14 feet high, may be entirely covered on four sides for less than $10; and one of 24 by 36 feet, and 20 feet high, for less than $25. The perfect tightness of the walls and non-conductibility of the material causes a saving in fuel, which for a single season is claimed to be considerably less than the above sums.

Serial: The Manufacturer and Builder Volume 0006 Issue 2 (February 1874)
Title: *Paper as a Building Material* [pp. 32-33]
Collection: Journals: Manufacturer and Builder (1869 - 1894)

Latest Market Report of Building Materials.

NEW YORK WHOLESALE PRICES.

ARTICLES MARKED WITH A STAR (*) ARE QUOTED IN GOLD.

—o—

LUMBER.

Pine, very choice and extra dry, per M	$65 00 a 70 00
Pine, good	55 00 a 60 00
Pine, good box	26 00 a 28 00
Pine, common box	21 00 a 23 00
Pine, common box, ⅝	15 50 a 17 50
Pine, tally plank, 1¼, 10 inch, dressed, each	42 a 45
Pine, tally plank, 1¼, 2d quality	36 a 38

HAIR—PER BUSHEL.

Cattle	— 20 a — 25
Goat	— 24 a — 30

STONE.—Cargo Rates.

Ohio Freestone, in rough, per cub. ft.	— — a 1 30
Ohio, Buena Vista, in rough	— — a 1 55
Berea Freestone, in rough	— — a 1 15
Brown Stone, Portland, Conn	1 25 a 1 50
Brown Stone, Belleville, N. J	1 00 a 1 50
Granite, rough	75 a 1 50
Dorchester, N.B., Stone, rough, per ton, currency.	— — a 15 00

PLASTER PARIS.

Nova Scotia, white, per ton	— — a 5 25
Nova Scotia, blue	3 50 a 4 00
Calcined, Eastern and city, per bbl	2 00 a 2 25

in lumber is a trifle better, and more activity has developed. The hardware market is fair and prices are generally well sustained. Lath and lime are unusually quiet and inactive, there being but a light jobbing demand. The brick market is very dull, while cement and hair are in very indifferent request.

Paper as a Building Material.

WE were not mistaken when we predicted a bright

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Testing in the 70's

- Large Buildings, special fans
- Standard blower door for housing
- Measure for interest/research
- Weatherization

STUDIES ON EXTERIOR WALL AIR TIGHTNESS
AND AIR INFILTRATION OF TALL BUILDINGS

GEORGE T. TAMURA, P.E.
Member ASHRAE

CHIA Y. SHAW, P.E.

ASHRAE Trans. 1976

One of the functions of the exterior walls of buildings is to separate out
inside environment. Building envelopes are not normally completely air ti
some flow of air into and out of them through joints and cracks in the wa
of air contributes to heating and cooling loads and must be taken into ac
analysis of buildings and design of HVAC systems.

Energy and Buildings, 2 (1979) 163 - 174

The Saskatchewan Conservation House:
Performance Results

ROBERT W. BESANT, ROBERT S. DUMONT, and GREG SCHOENAU
Department of Mechanical Engineering, University of Saskatchewan, Saska

(Received August 2, 1978)

1977: 1 ACH@50Pa

BUILDING PRACTICE NOTE

NRCC/DBR 1982:
40 homes Built 1977-1980 (Canadian Prairies)
Avg 1.42 ACH@50 Pa

LOW ENERGY PRAIRIE HOUSING

A Survey of Some Essential Features

by

R.S. Dumont, H.W. Orr, M.E. Lux

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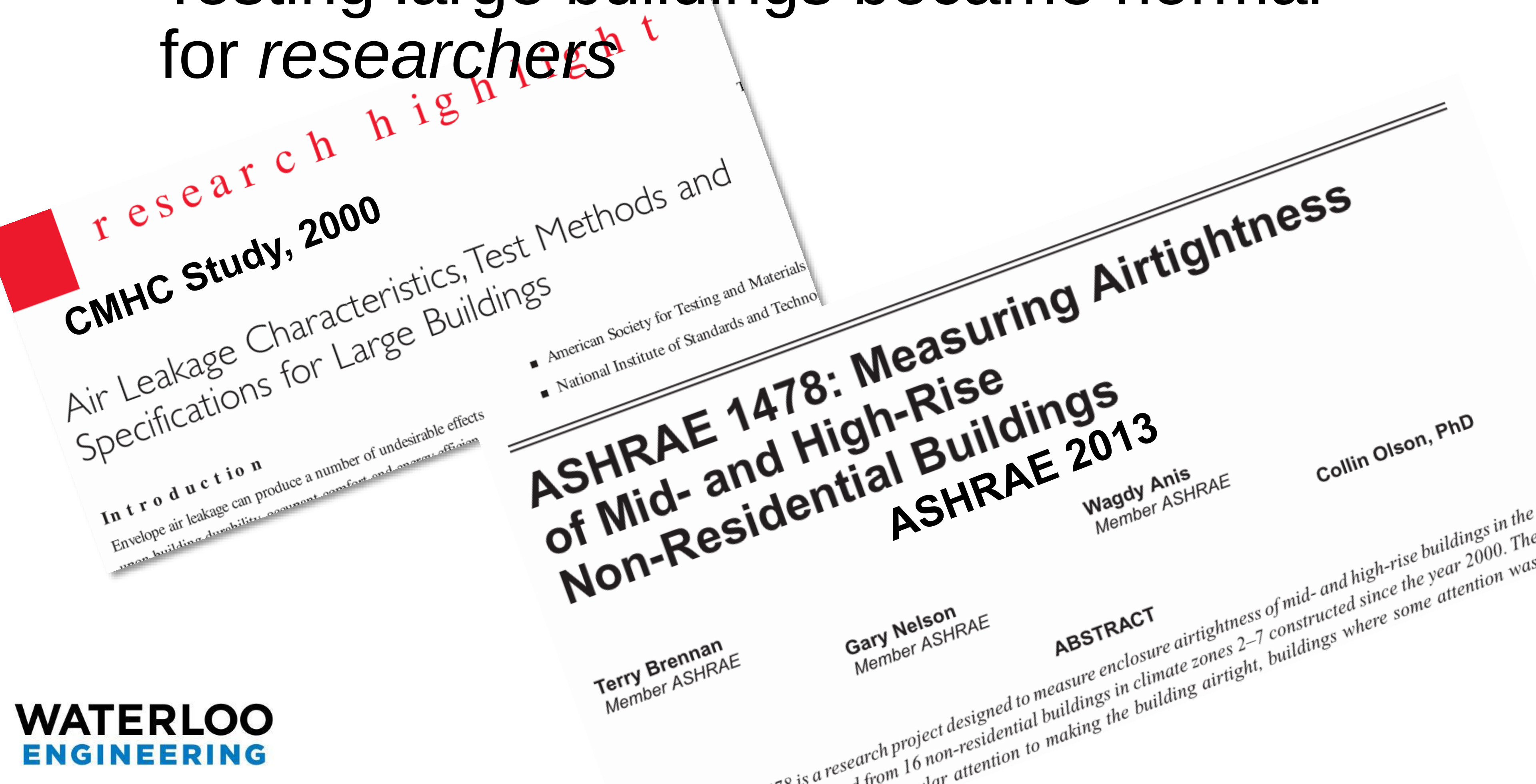
2000’s

- Testing large buildings became normal for *researchers*



research highlight

CMHC Study, 2000

Air Leakage Characteristics, Test Methods and Specifications for Large Buildings

- American Society for Testing and Materials
- National Institute of Standards and Techno

Introduction

Envelope air leakage can produce a number of undesirable effects

ASHRAE 1478: Measuring Airtightness of Mid- and High-Rise Non-Residential Buildings

ASHRAE 2013

Terry Brennan, Member ASHRAE

Gary Nelson, Member ASHRAE

Wagdy Anis, Member ASHRAE

Collin Olson, PhD

ABSTRACT

…78 is a research project designed to measure enclosure airtightness of mid- and high-rise buildings in the … from 16 non-residential buildings in climate zones 2–7 constructed since the year 2000. The … attention to making the building airtight, buildings where some attention was

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Current State

- Following the leadership of GSA and US ACE, whole building airtightness is entering the mainstream
- Other owners with long-term stake in building are specifying it
- State & City codes are beginning to require it

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Why whole building airtightness testing?

- 1. Demonstrate compliance
  - Most reliable and accurate means of showing codes/standards/specs are met
- 2. Quality Control
  - Measurement of complete product (building) to confirm airtightness
- 3. Diagnostic
  - Aid to identify where leaks are and if repairs are effective

Why airtightness?

- Comfort
- Health
- Moisture
- Energy
- Code
- Standards (e.g. ASHRAE, PassivHaus)

Definitions (ABAA)

- **Air Barrier System:** The combination of air barrier assemblies and air barrier components, connected by air barrier accessories that are designed to provide a continuous barrier to the movement of air through an environmental separator (e.g. the building enclosure).
- **Air Barrier Assembly**: The combination of air barrier materials and air barrier accessories that are designated and designed within the environmental separator to act as a continuous barrier to the movement of air through the environmental separator.
- **Air Barrier Component**: Pre-manufactured elements such as windows, doors, and service elements that are installed in the building enclosure that form part of the air barrier system.
- **Air Barrier Material**: A building material that is designed and constructed to provide the primary resistance to airflow through an air barrier assembly.
- **Air Barrier Accessory**: Any construction material that is used to join air barrier materials, air barrier assemblies, and air barrier components

Targets, e.g. GSA

- Common (e.g., GSA

  Material: 0.02 lps/m^2 @75 Pa= 0.004 cfm / ft^2 @0.3"wg

  Component: 0.2 lps/m^2 @75 Pa= 0.04 cfm / ft^2 @0.3"wg

  Building: 2.0 lps/m^2 @75 Pa= 0.4 cfm / ft^2 @0.3" wg
- USACE 1.25 lps/m^2 @75 Pa (0.25 cfm)
- DOE "Future" 0.25 lps/m^2 @75 Pa (0.05 cfm)

Targets?

TABLE 4.1 WHOLE BUILDING AIRTIGHTNESS PERFORMANCE REQUIREMENTS FOR CANADA AND THE UNITED STATES (RETROTEC, 2012)			
Standard	**Region**	**Comments**	**Requirements**
USACE	USA	Large Buildings	1.27 L/(s·m²) @ 75 Pa
		Large Buildings (Proposed)	0.76 L/(s·m²) @ 75 Pa
GSA	USA	All Buildings	2.03 L/(s·m²) @ 75 Pa
2012 Washington State Energy Code	Washington State	Commercial Buildings	2.03 L/(s·m²) @ 75 Pa
2012 Seattle Energy Code	Seattle	Commercial Buildings	2.03 L/(s·m²) @ 75 Pa
IBC/IECC	Model Code	Commercial Buildings in Climate Zone 4 – 8	2.03 L/(s·m²) @ 75 Pa
IGCC	Model Code	Commercial Buildings	1.27 L/(s·m²) @ 75 Pa
LEED	USA	All 6 surfaces enclosing an apartment.	1.17 L/(s·m²) @ 75 Pa
LEED Canada	Canada	All 6 surfaces enclosing an apartment.	1.52 L/(s·m²) @ 75 Pa
Passive House (Canada	Canada	All buildings	0.6 ACH_{50}

Different targets

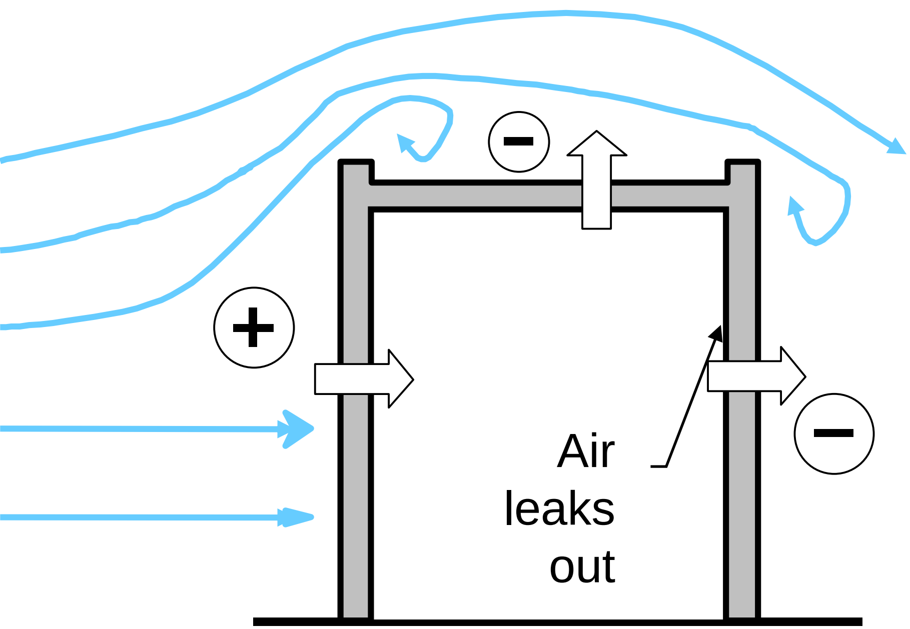
- *Building* leakage requirement most important for
  - energy,
  - interior RH,
  - some IAQ
- *Component* leakage requirement *may* matter more for
  - air leakage condensation control,
  - Comfort, IAQ

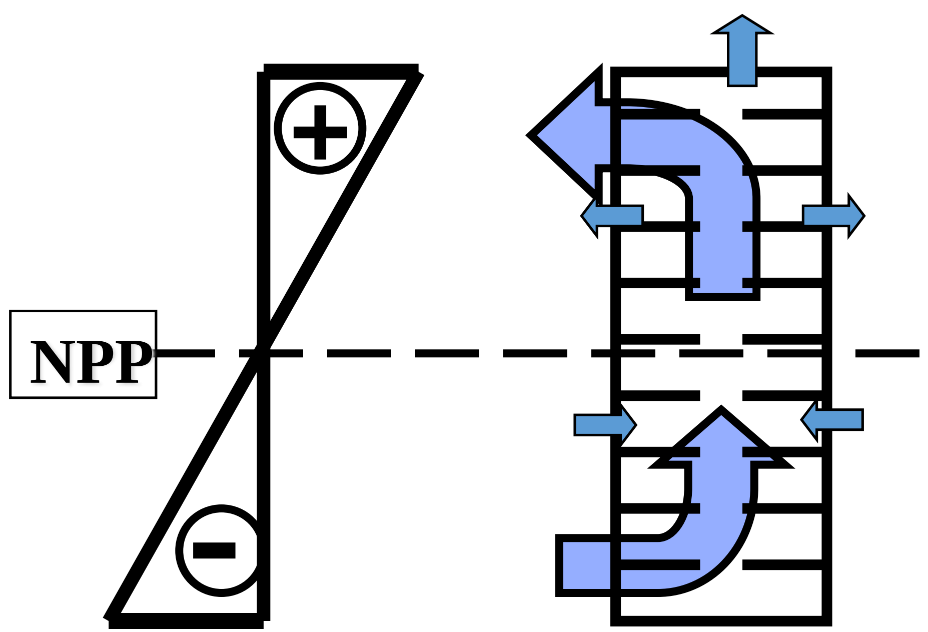
Do materials matter?

- Building target 0.4 cfm/sf@0.3 in w.g.
- Assume material “fails” requirement
  - E.g. 2x max = 0.008 cfm/sf@0.3” w.g.
  - “Failure” causes 1% increase in flow
- Even for “tight” homes
  - 0.6 ACH target
  - “Failed” material adds about 0.75%
  - Equals about 0.01 ACH

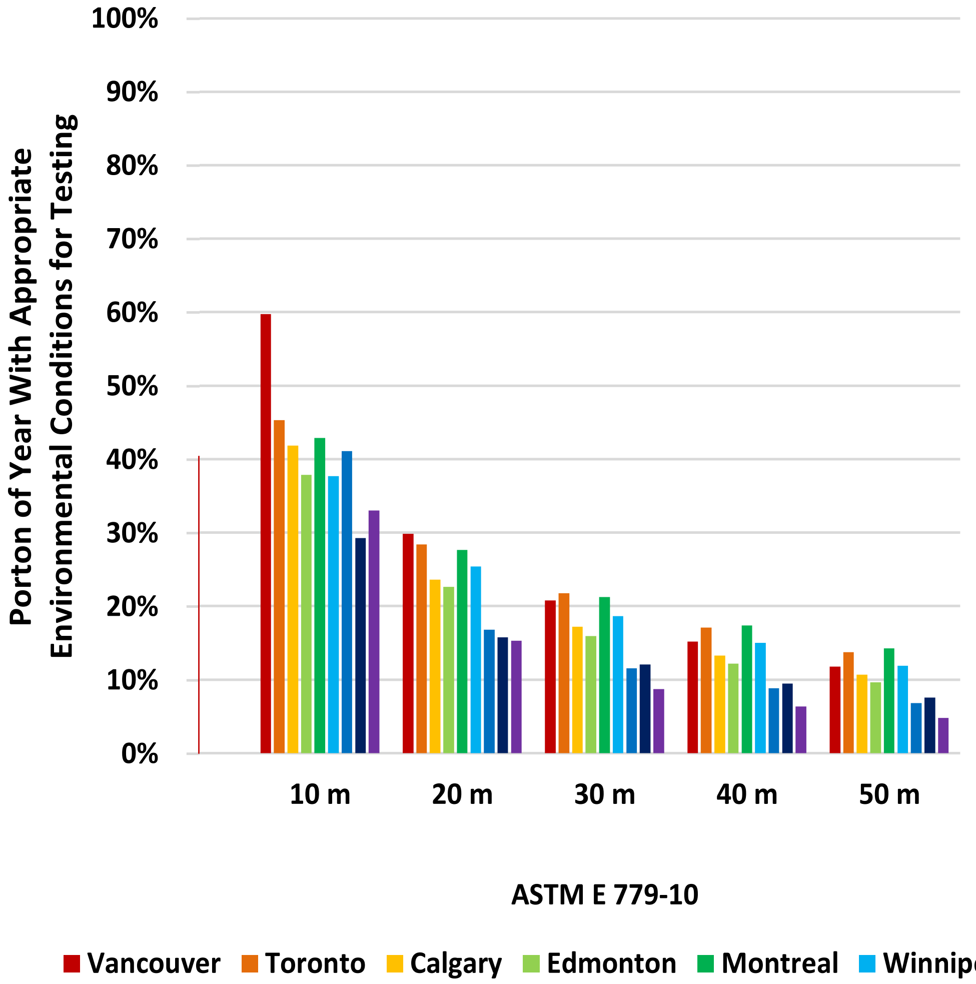
Pressures During Test

- Wind & Stack
- If too large, can't test





When can one test?



Tall buildings wont be “testable” if it is windy and/or cold

Often we find “windows” of opportunity

Reporting Metrics

- ACH @ pressure (usually @50 Pa = 0.2”)
  - Volumetric flow rate / volume
- Permeance (usually @50 or 75 Pa)
  - Volumetric flow rate / area
  - What area?

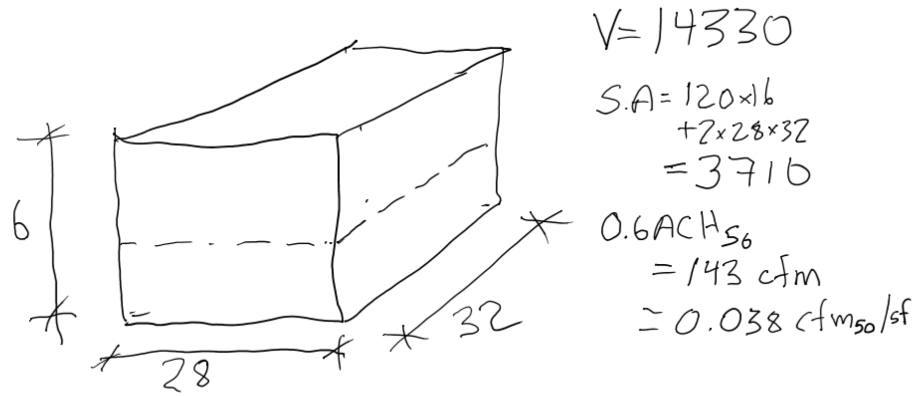
    all six sides of enclosure
- Higher pressures are both possible and preferable for measurement accuracy

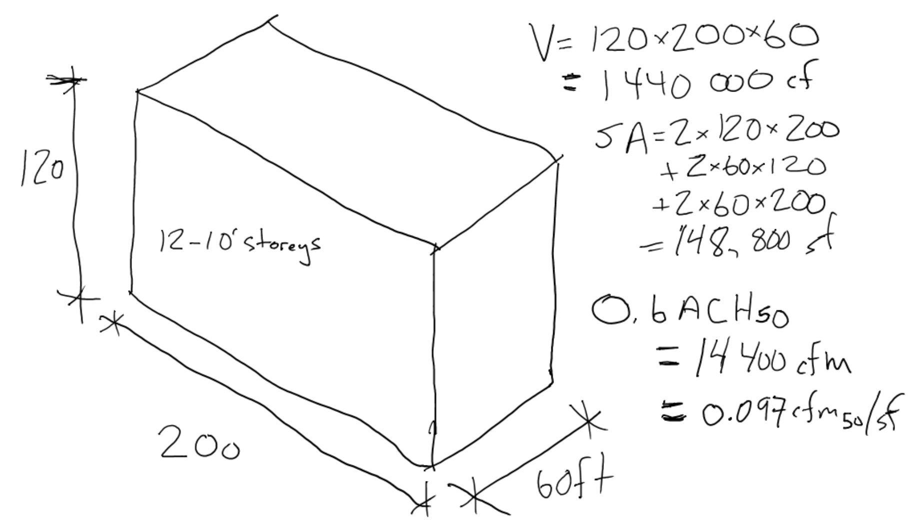
Measurement Reporting

- Common to use ACH@50 for houses
  - This is not a good metric for *enclosures*
- Industry has chosen cfm/sf @ 75 Pa for *commercial* buildings
  - Accounts for enclosure : floor ratio
  - Which test? Pressurization or Depressurization? Average
- Use of total enclosure area is common
  - Check that the area used includes slab
  - Where is conditioned/unconditioned space?

Why ACH is a poor metric

- e.g. a 2 story house vs hi-rise apt. @0.6ACH$_{50}$
- House 0.038 cfm$_{50}$/sf
  vs
- Apartment 0.097 cfm$_{50}$/sf
- Large buildings can easily meet low ACH targets
- But relation to performance?





Measuring Airtightness

- Usually use ASTM E779 /E1827 (in North America)
- May use building airhandler if flow can be measured accurately (e.g. CGSB)
- Buildings over 800 000 sf and 30 stories have been tested to date
- USACE has best protocol IMHO, supported by best ASHRAE research

How to measure?

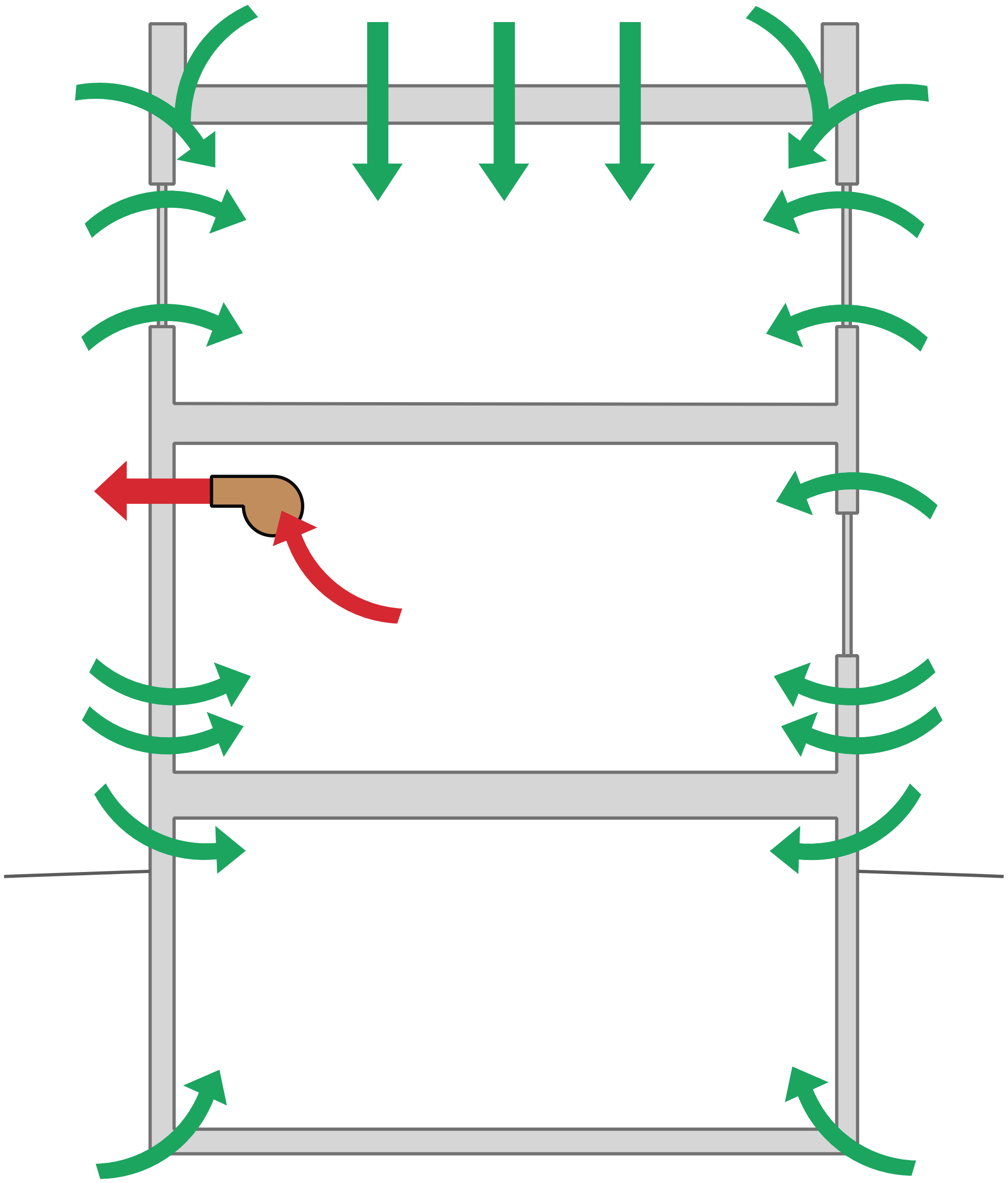
- Pressurize/depressurize
  - Unlike in houses, *both* are recommended
- Seal / damper intentional holes
  - Beware operational reality vs test
- Limit testing when pressures imposed
  - Stack effect
  - Wind
  - Important issues for large buildings

Blower doors…

- Imposes Uniform Air pressures
- Real life is not uniform

Test results therefore…

- Cannot directly or accurately predict in-service air leakage
- HVAC pressurization can begin to approach leakage of test

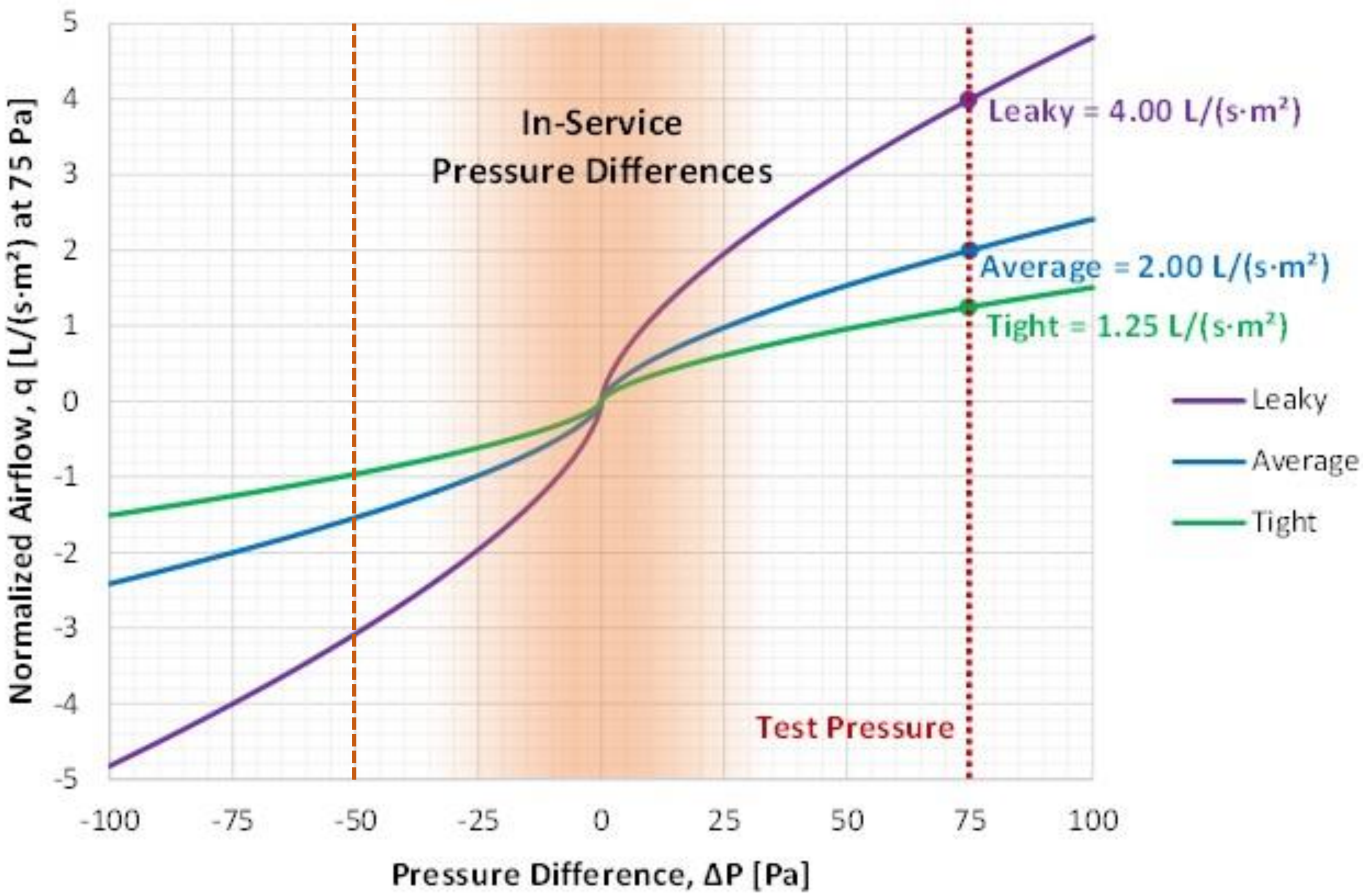


Airtightness testing will **not** tell you exactly how much a building will leak in operation

Need more info… where is leakage, what pressure building operates at (HVAC is a big factor)

Test vs Service pressure

•



Air Leakage Testing



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Excellent Reference.

http://www.wbdg.org/pdfs/usace_airleakagetestprotocol.pdf

US Army Corps of Engineers®
Engineer Research and Development Center

air barrier
abaa
association of america

U.S. Army Corps of Engineers
Air Leakage Test Protocol for Building Envelopes

Version 3 - May 11, 2012

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Practical Issues: A Big Deal

- Occupancy– doors opening, bathroom fans operating, HVAC operation?
- Security/Safety- opening doors to connect interior spaces together
- Control & Power. How to control many different blowers How to power same.
- Sealing. Need to access and seal many HVAC vents grilles, etc.

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Large Building Air Leakage Testing

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Sealing Openings

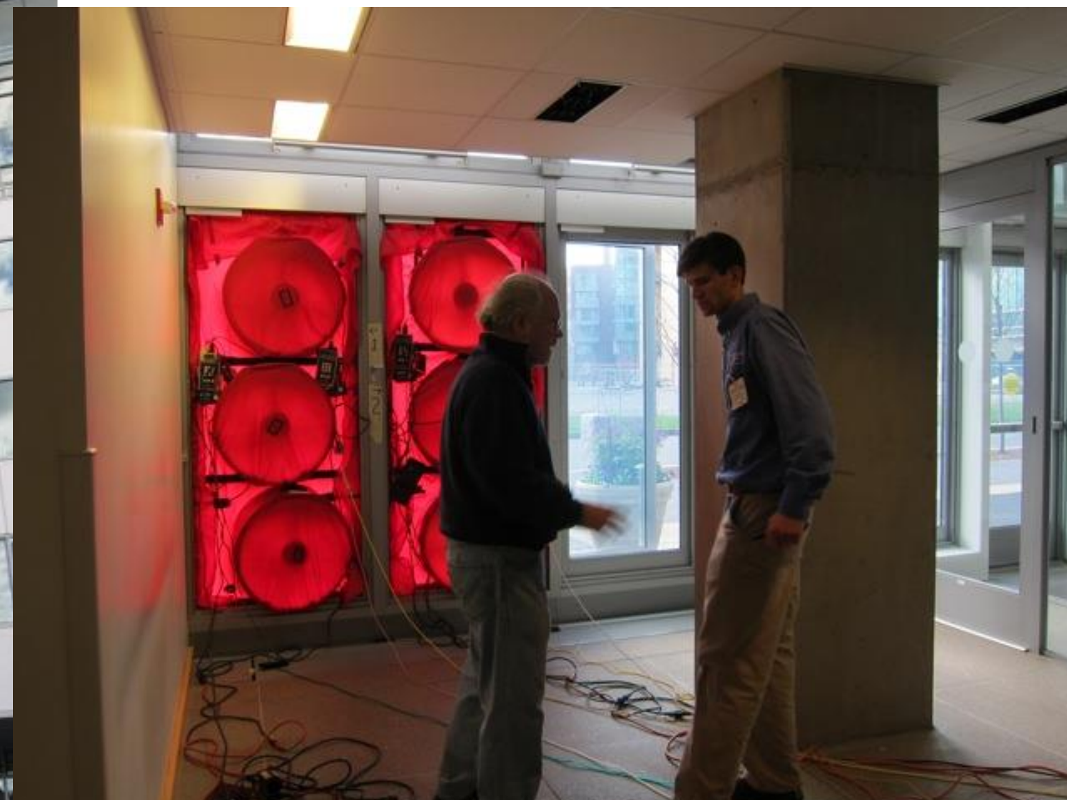
•

- Power Supply: 15A-20A per door

Whole-Building Testing

- Test early if you **must** hit a target
- Design enclosure for **testability**
  - Construction sequencing!
- Test before most of air barrier system is covered by other layers
- Do mockups
- Confirm trades are executing early

Air Leakage Testing



Photos: Building Science Corporation, Kohta Ueno

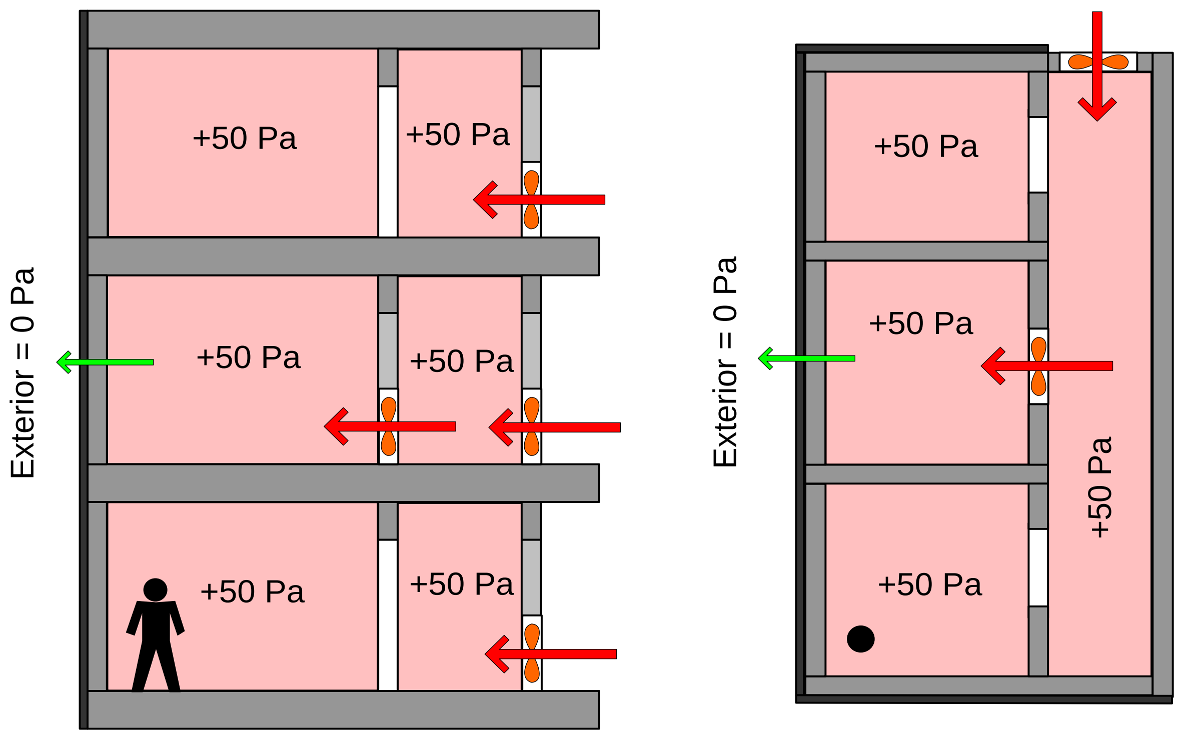
HVAC Systems

- Grills, louvers, dampers, vents are all penetrations of the air barrier system
- Become one of the largest sources of leakage in “good” buildings
- Typically these are excluded from targets, but should be measured if you can

Compartmentalization

- Construction sequencing
- Managing size
- Research

Test # 6 – Pressurize Suite and All Adjacent Interior Surfaces



Section View – Floor Above and Below

Plan View – Test Floor

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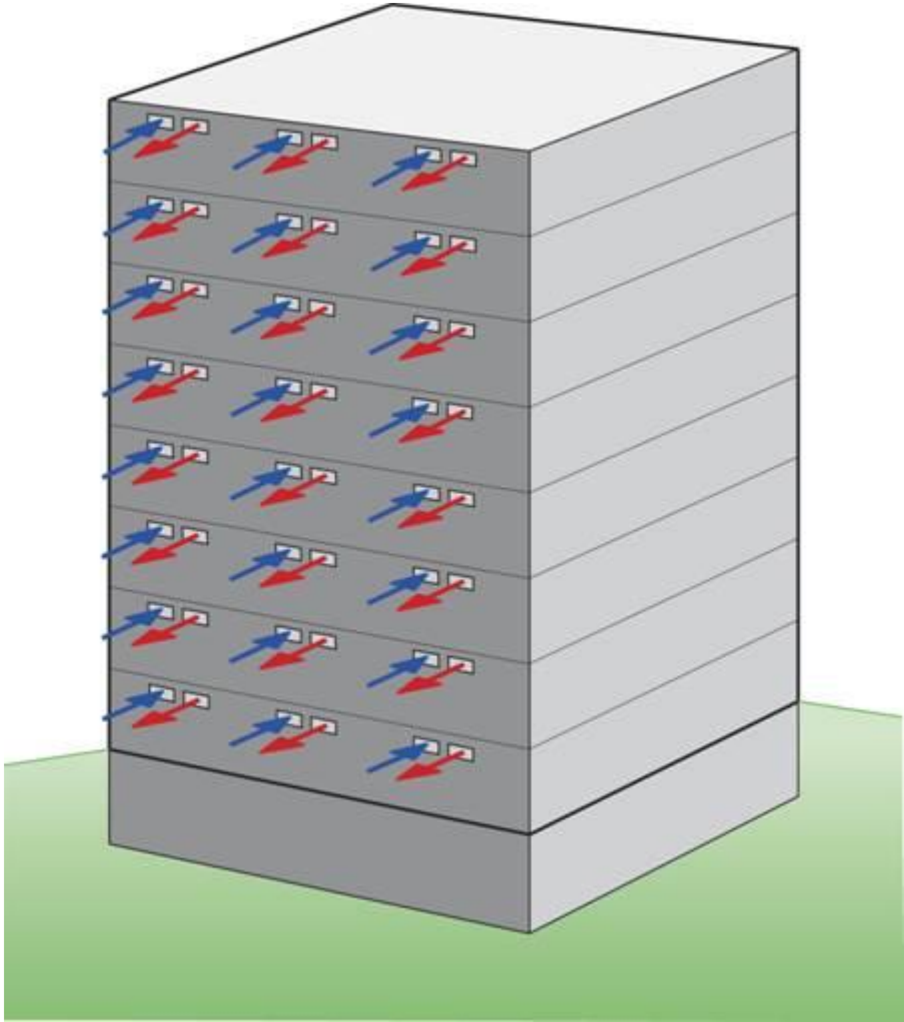
Many suites / many holes

- Significant effort required for multi-unit buildings…..
- Depressure easier



What to do with results?

- First, find the leaks
- Commonsense/experience is helpful
- ASTM E1186 *Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems*
- IR camera, smoke, hand

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Verification Testing

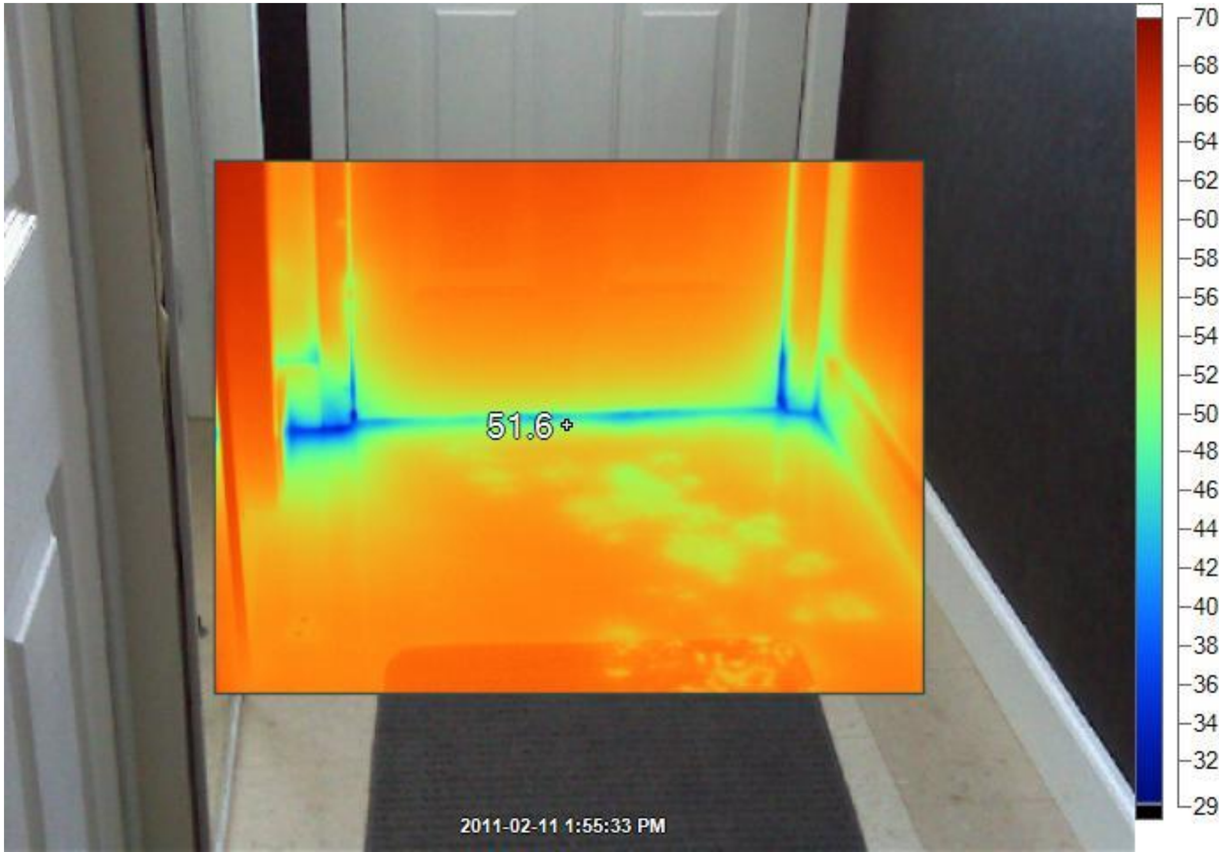
Mockups: Confirm design can be built and perform
In-situ testing: Verify that enclosure is built as per design=mockup

Smoke / visualization

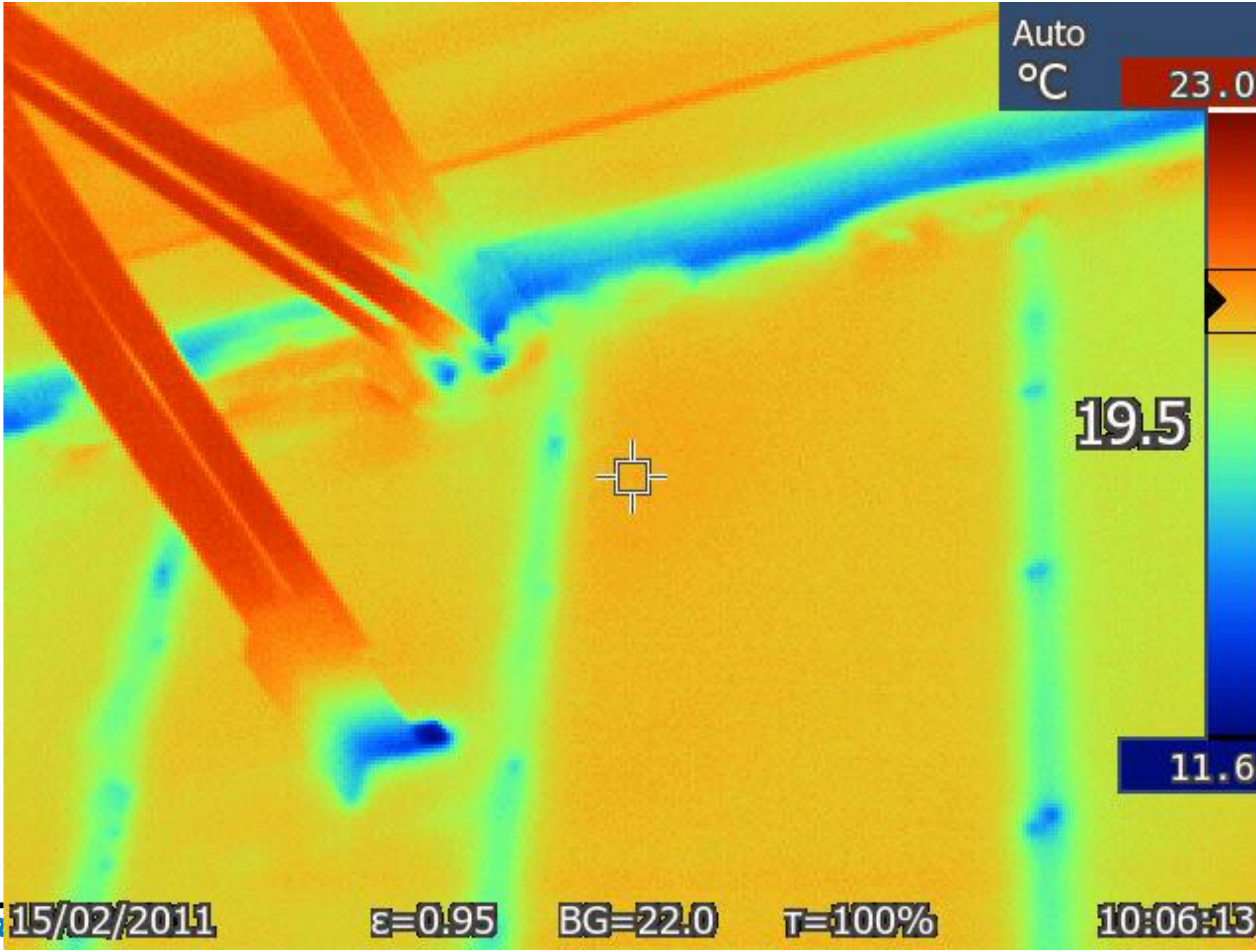
- Especially useful diagnostically
- Demonstration to trades

IR Camera

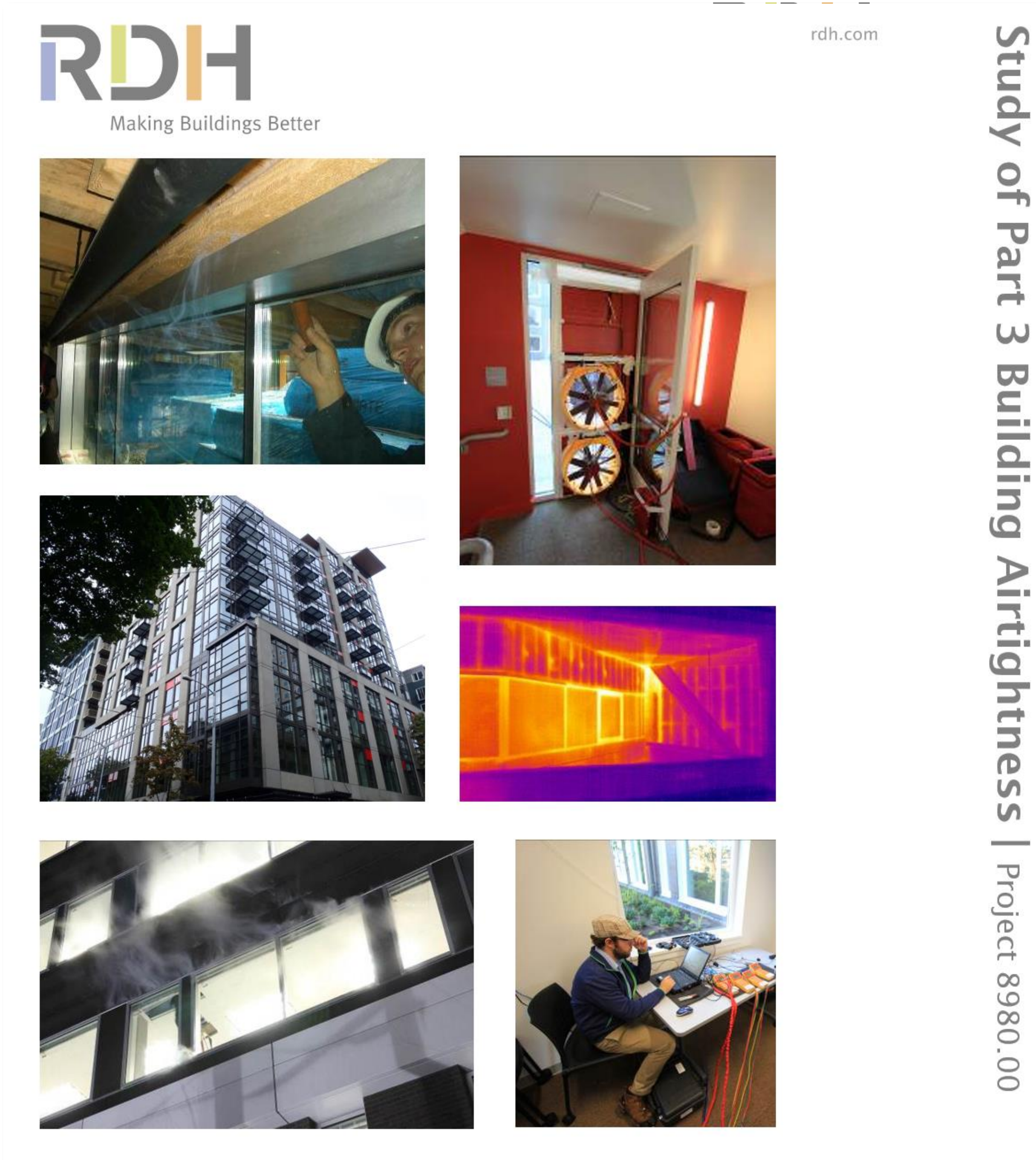
- Requires skilled operator
- Temperature difference
- Flow inward, then outward



Air leak or thermal bridge?



- Recent study for the Canadian code development



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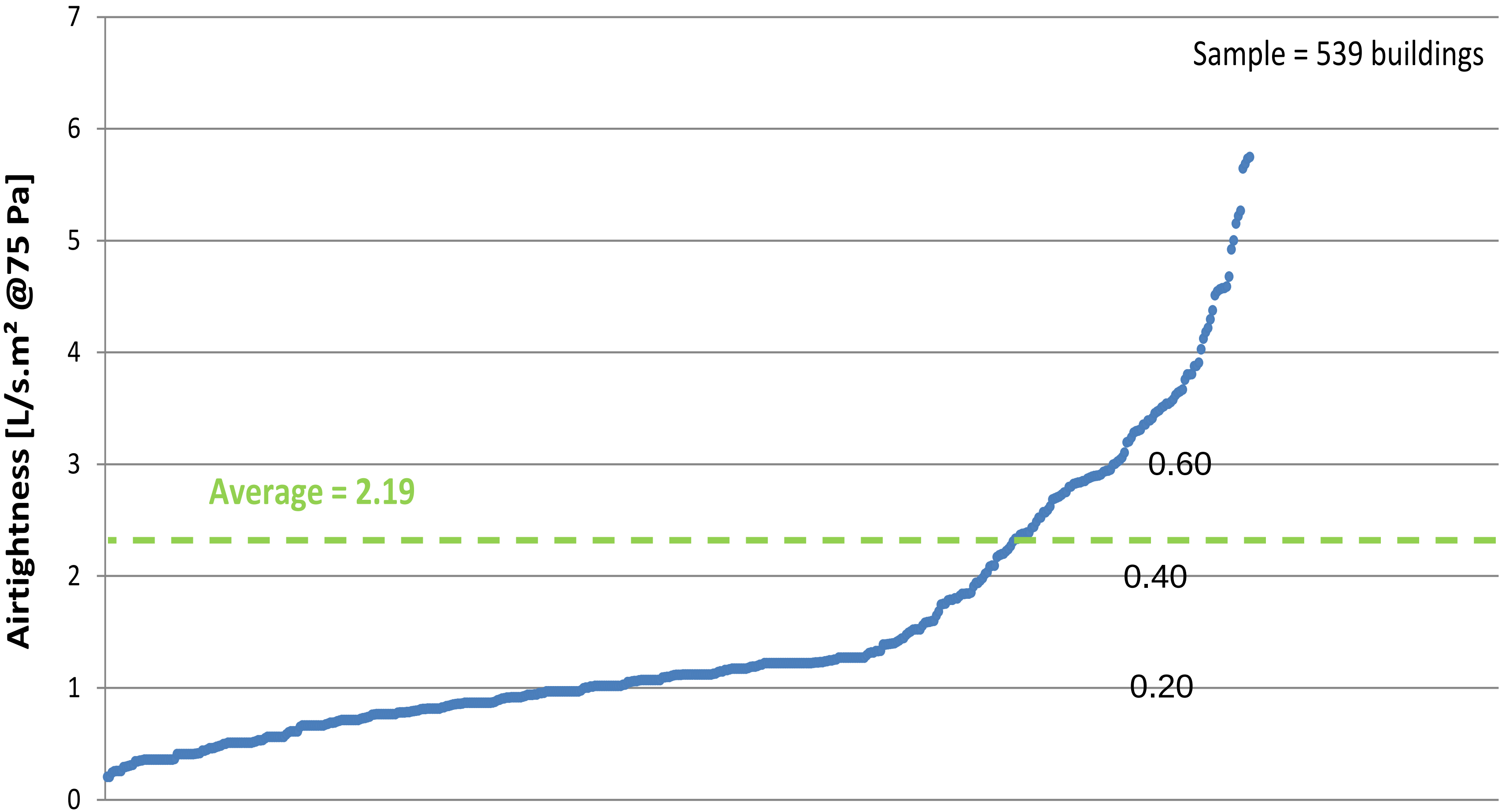
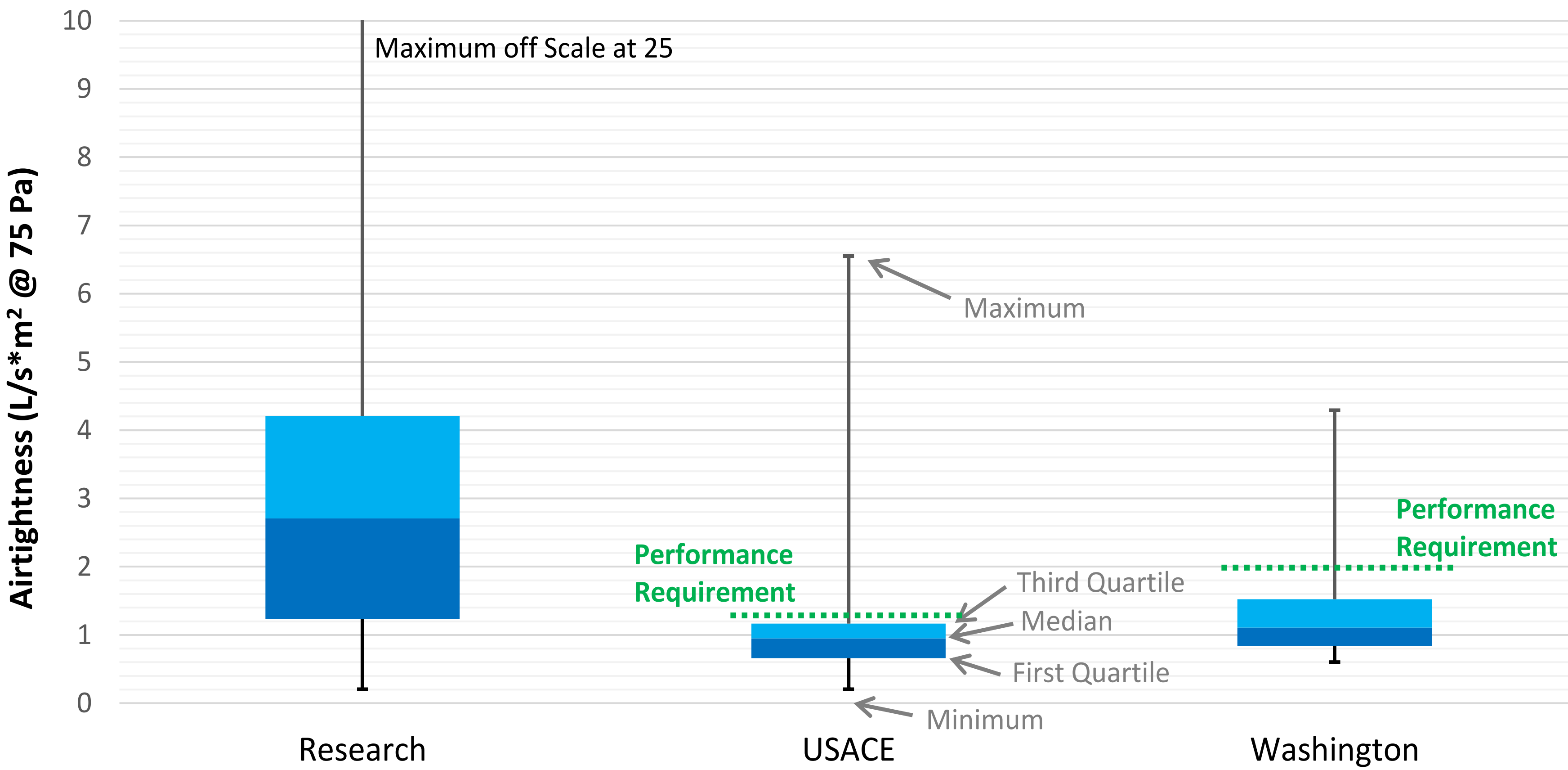
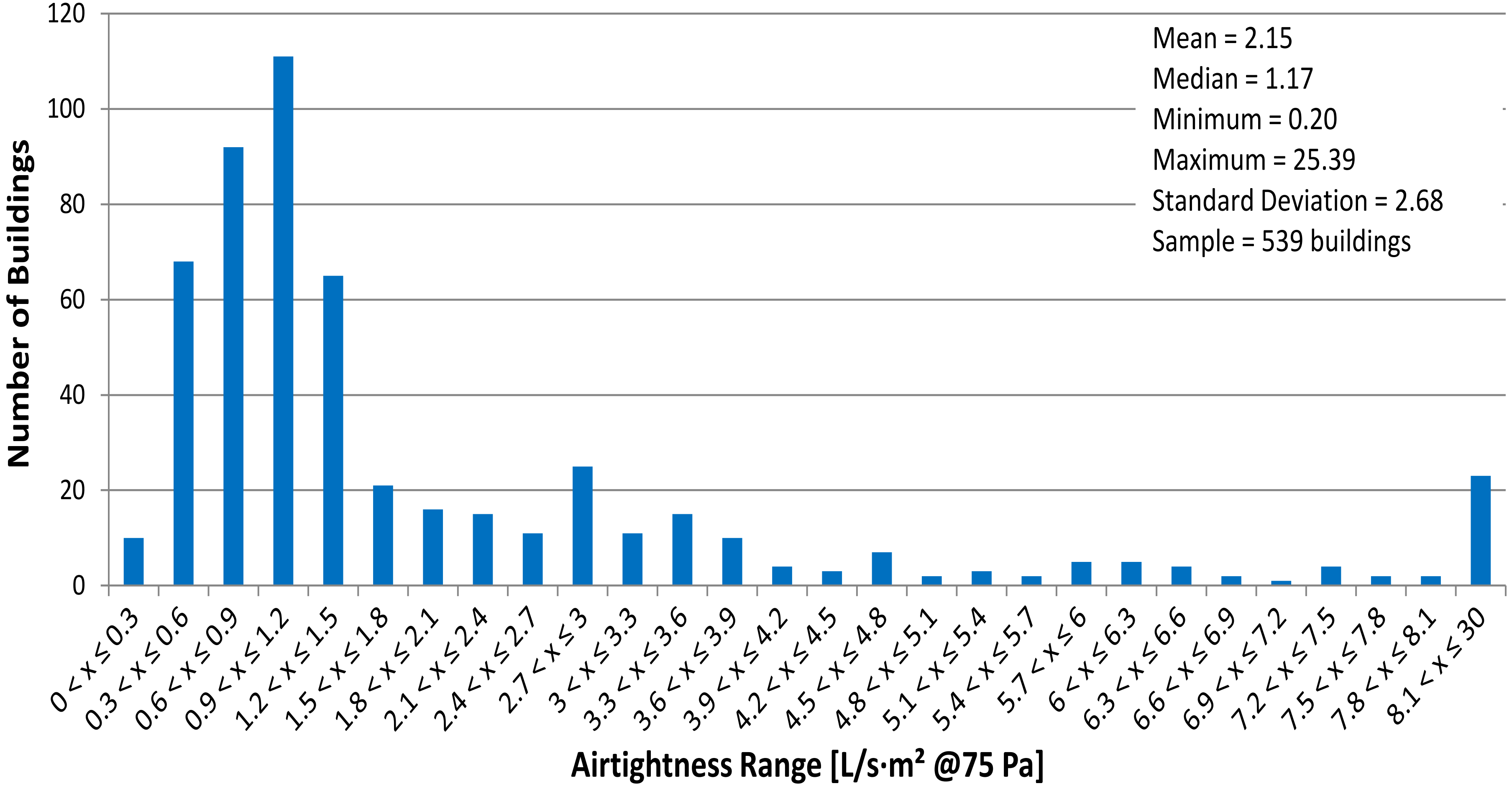
Air Permeance



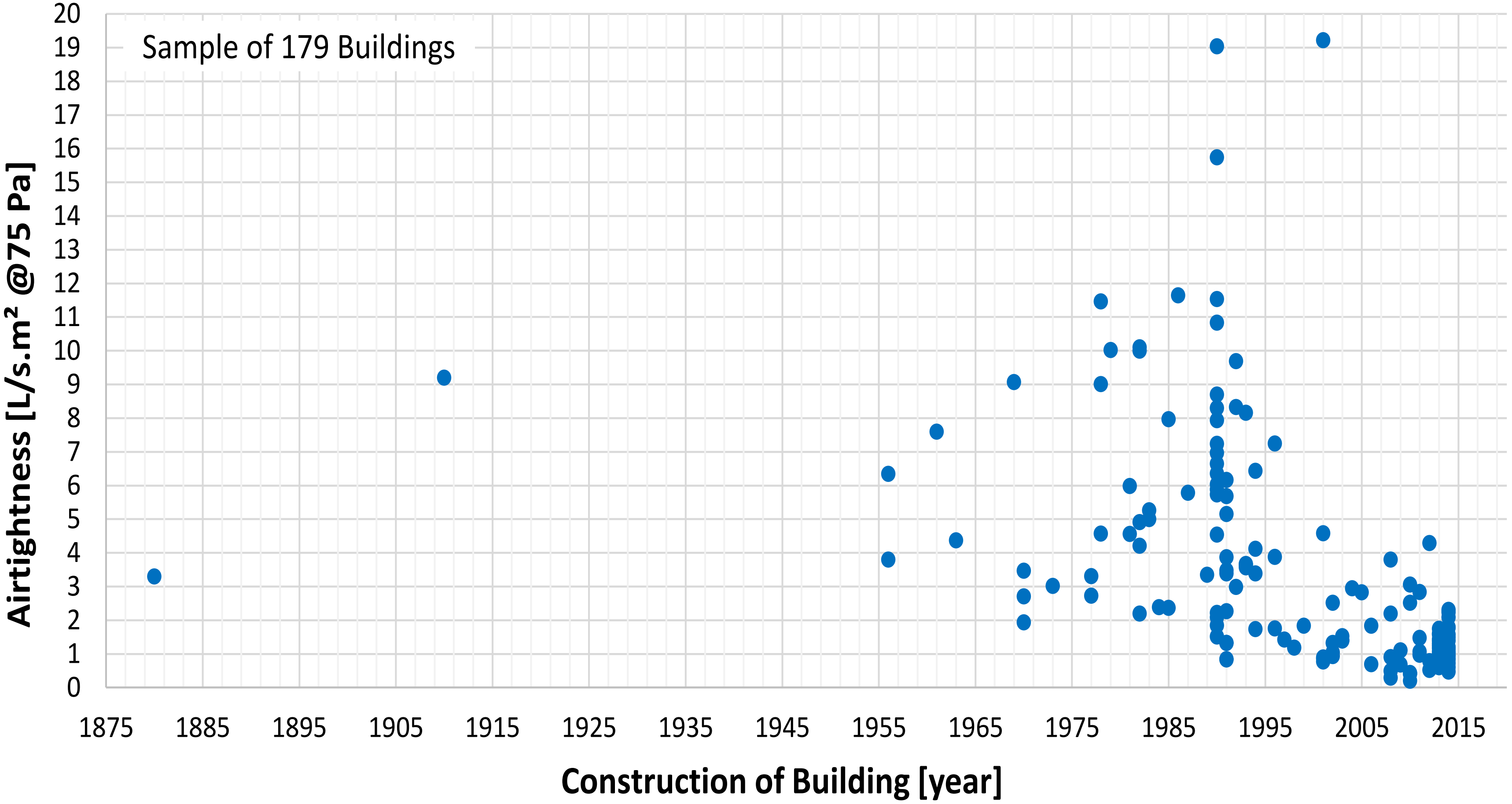
Influence of requirements



Airtightness distribution

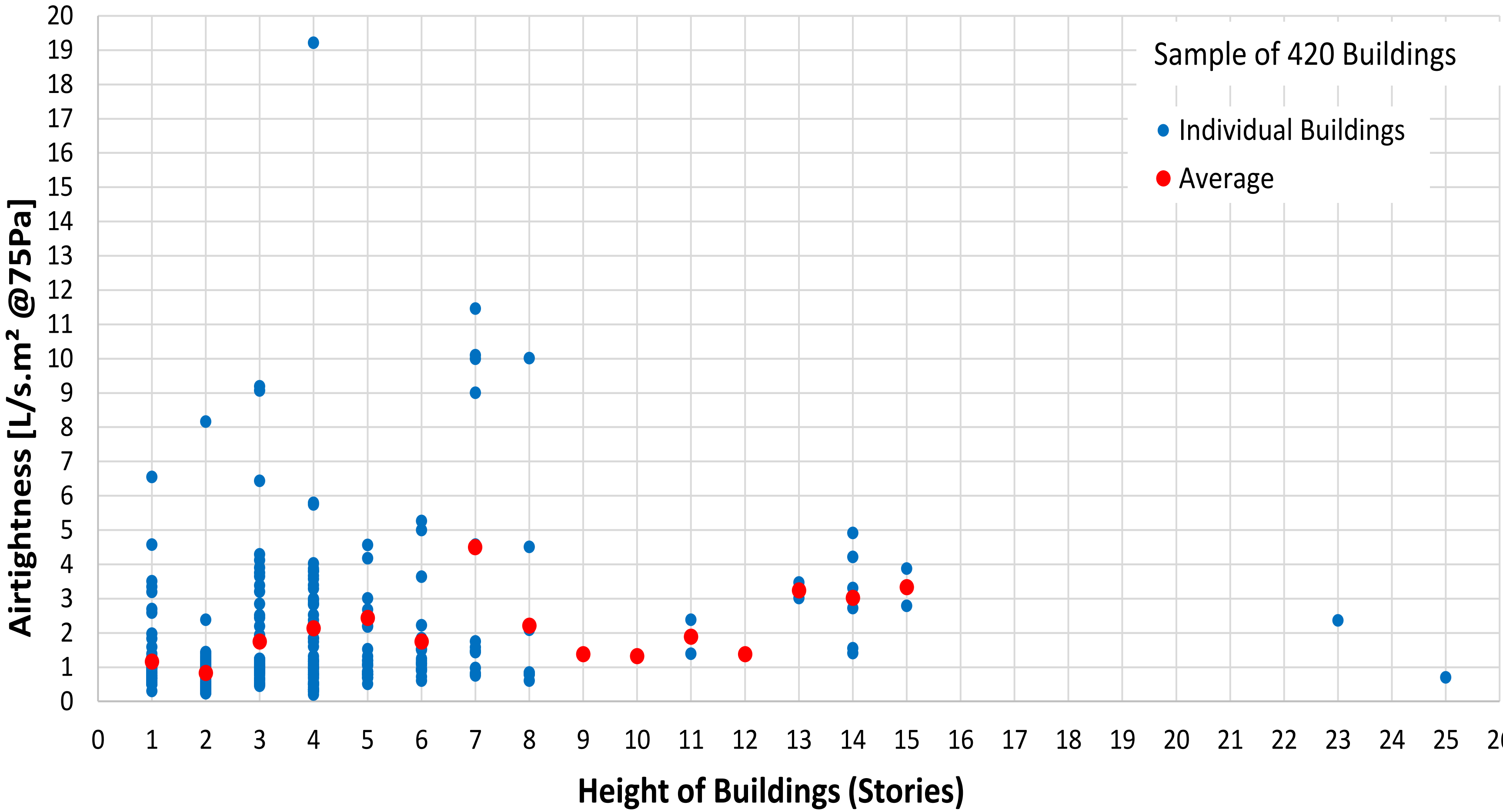


Age

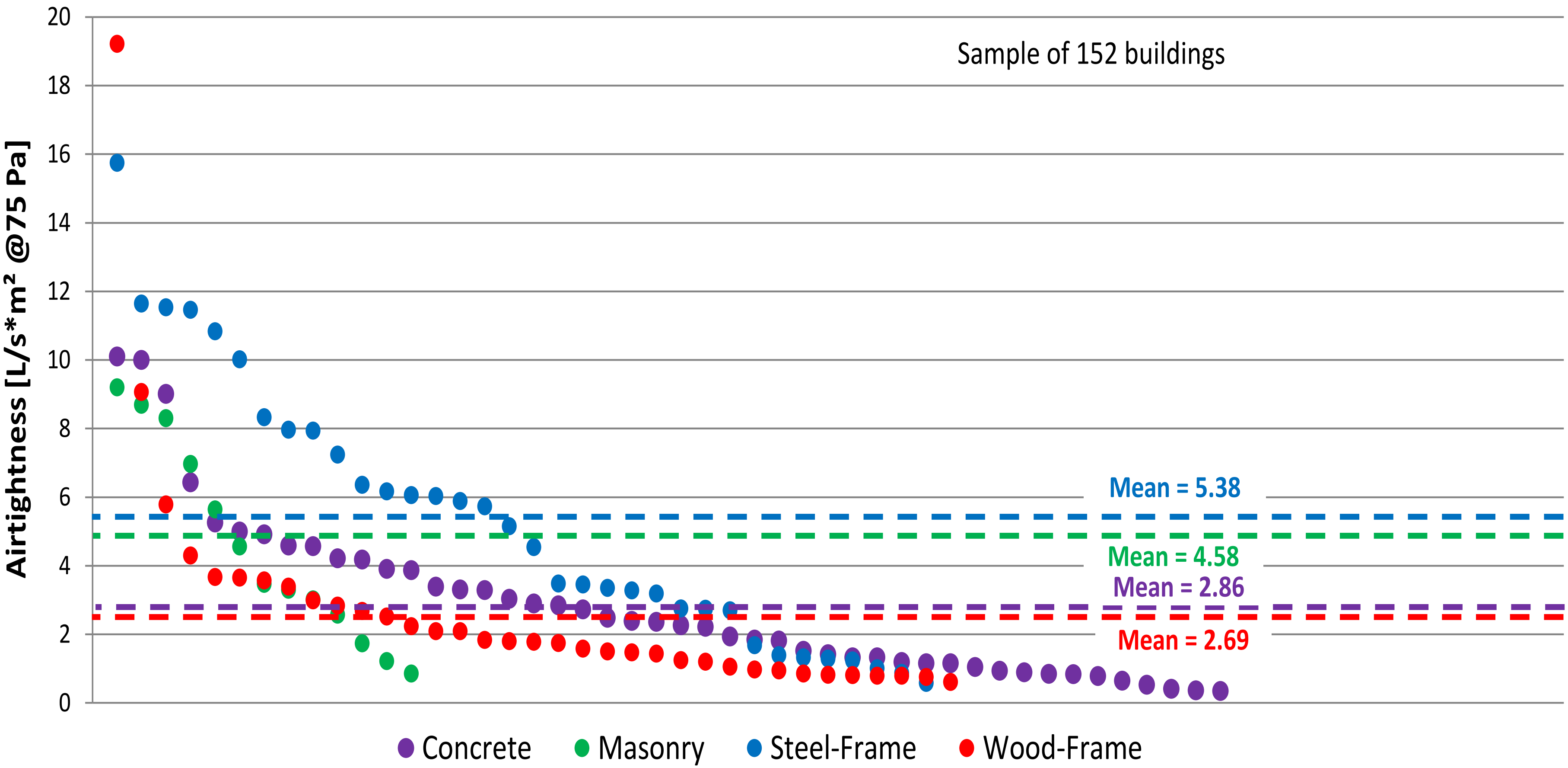


Sample of 179 Buildings
Airtightness [L/s.m² @75 Pa]
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1875
1885
1895
1905
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005
2015
Construction of Building [year]

Airtightness vs Height



Building "Construction"



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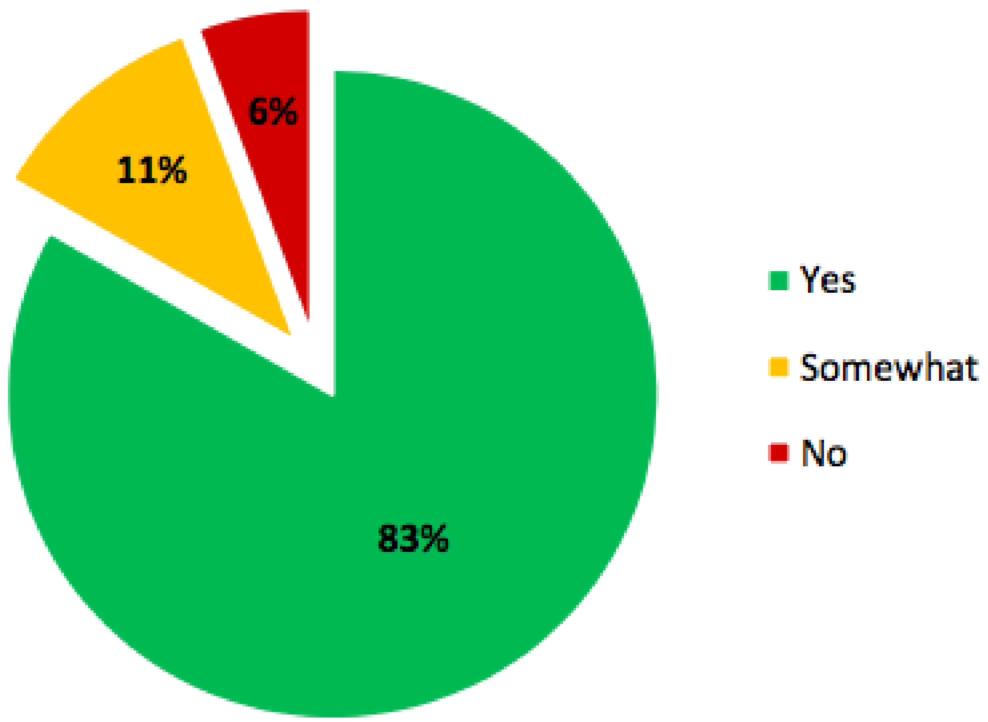
Is it worthwhile?

- Sample of 79 stakeholders



Future

- Techniques to ensure economy and utility rather than scientific accuracy
- More complimentary techniques to extract full value

Future: How tight? How leaky?

- Little research to support targets
- Field experience suggest commercial targets are getting good
- Housing/small buildings may need different targets
- Humidifed / special buildings need special targets.

Conclusions

- Testing of large buildings is here, and practical / economical
- Lots of information of value can be extracted
- Key part of building quality assurance
- Improvements remain: very tall, wind, sealing HVAC

What to do with results?

- First, find the leaks
- Commonsense/experience is helpful
- ASTM E1186 *Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems*
- IR camera, smoke, hand

Language

- Massive industry confusion
  - No clarity of communication = no clarity of thought
- Is an air barrier a product? A Function?
  - E.g. Tyvek, Blueskin
- Vapor barrier
- What about WRB, Housewrap, damproofing, waterproofing, roofing, underlayment, etc.

Combined functions

- Air barriers
- Air & water resistive barriers
- Air & vapor barriers
- Air, water, and vapor

- Air-water-thermal
- Air-water-vapor-thermal

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Roof Air Barrier?

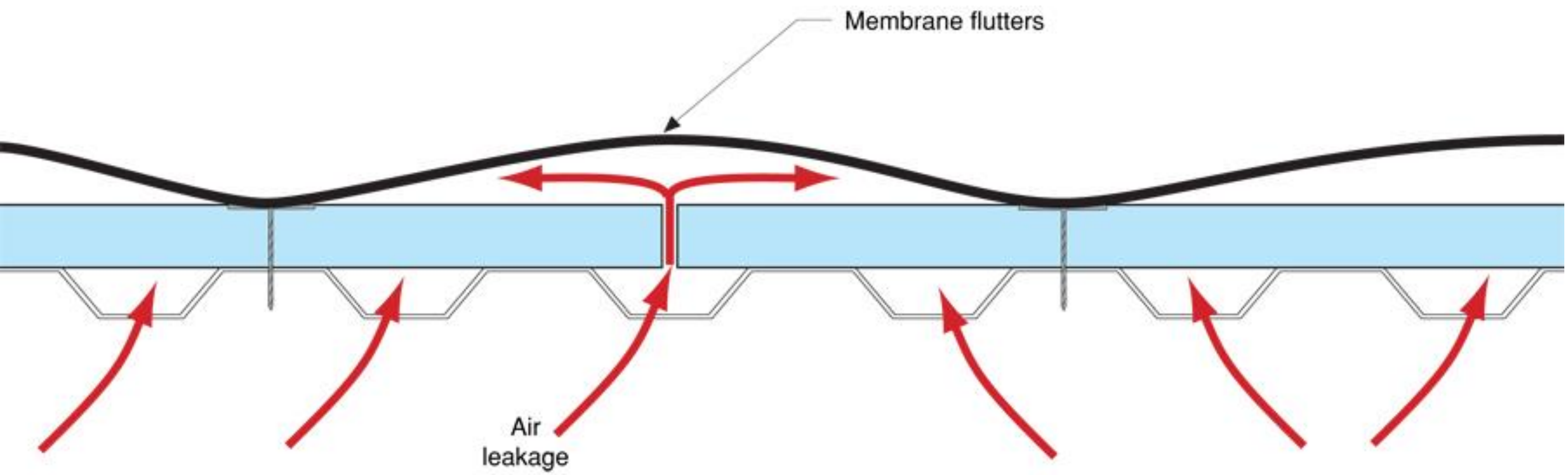
Problems

No deck Air Barrier

+ No fully-adhered membrane

+ White Roof

= accumulation of moisture & failure



From: Straube, J.F. *High-Performance Enclosures*, Building Science Press 2012.

Slabs, Radon, soil gas

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Poly Air-Vapor barrier

- Label of “vapor barrier” created lots of confusion
- Flexible membrane hard to seal

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Poly and butyl sealant

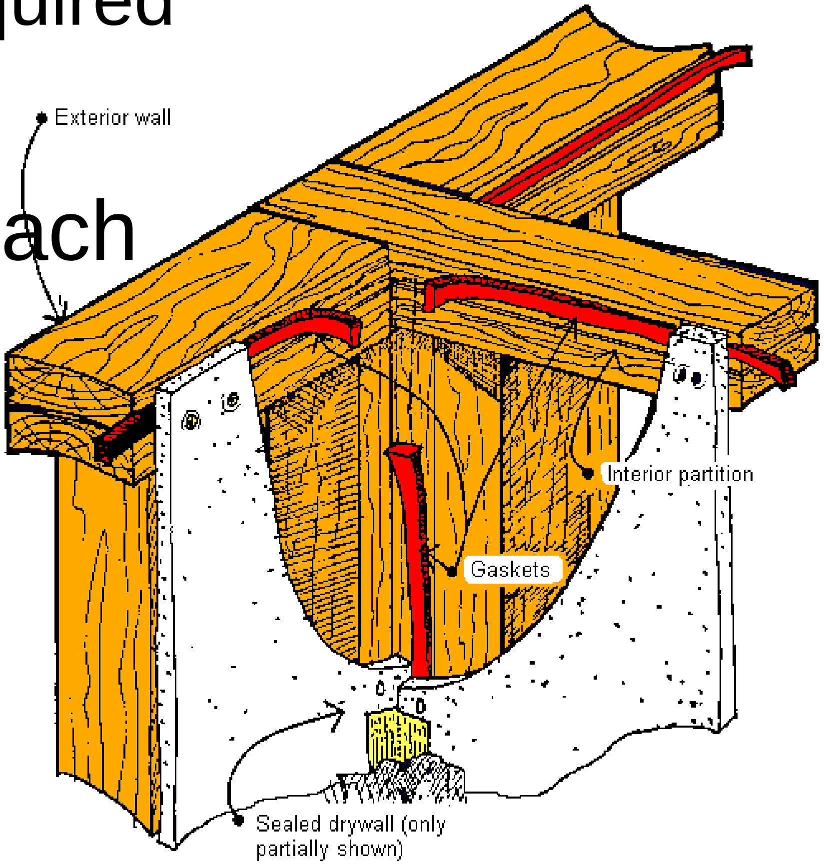
- Original scientific approach 1970’s

Targets

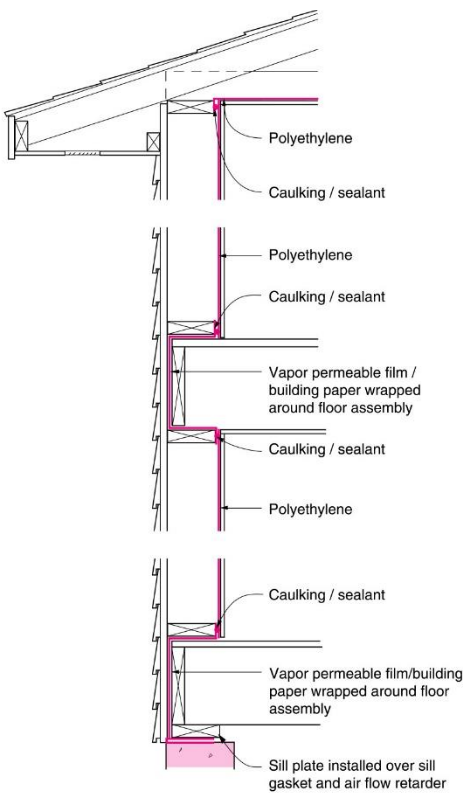
- R-2000 approx. 1984
  - Max 1.5 ACH@50 required

- Airtight Drywall Approach

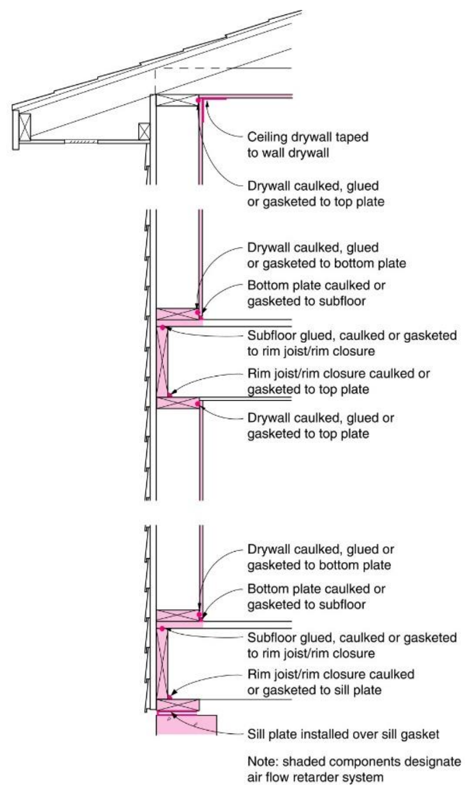
- Poly continued to be promoted



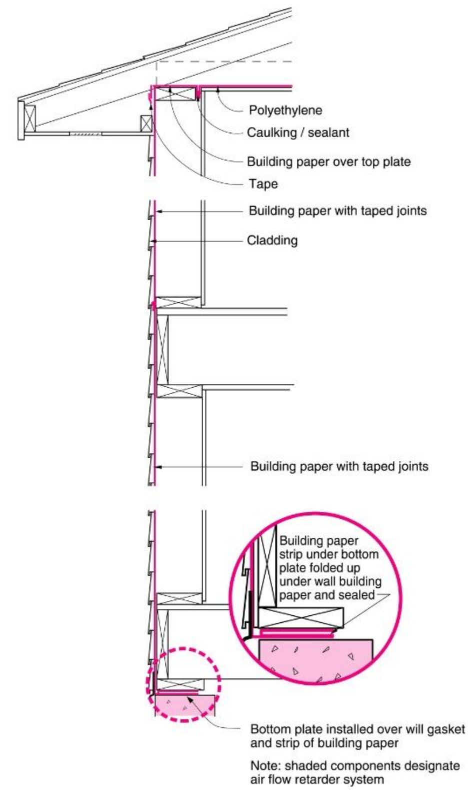
Evolution of location



Interior Air Flow Retarder Using Polyethylene



Interior Air Flow Retarder Using Drywall and Framing



Exterior Air Flow Retarder Using Building Paper or Housewrap

Breakthrough: permeable air barrier

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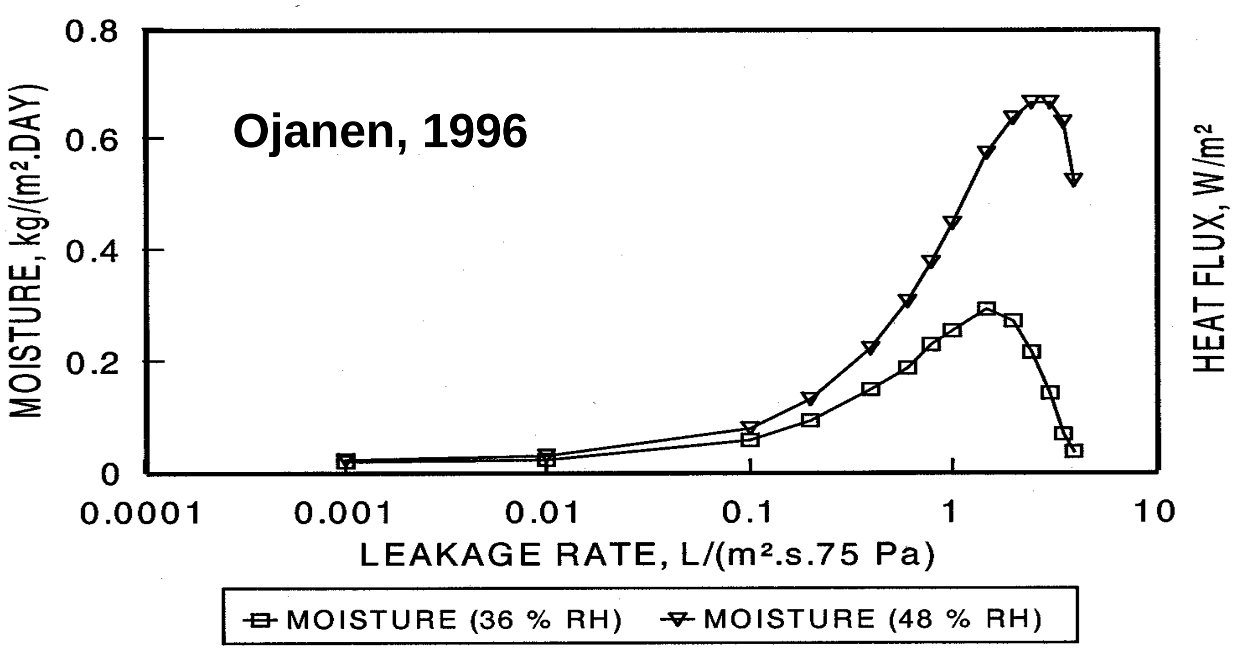
How much leakage allowable

- Research suggested low air leakage rates to prevent moisture damage
- Assumed climate and assembly



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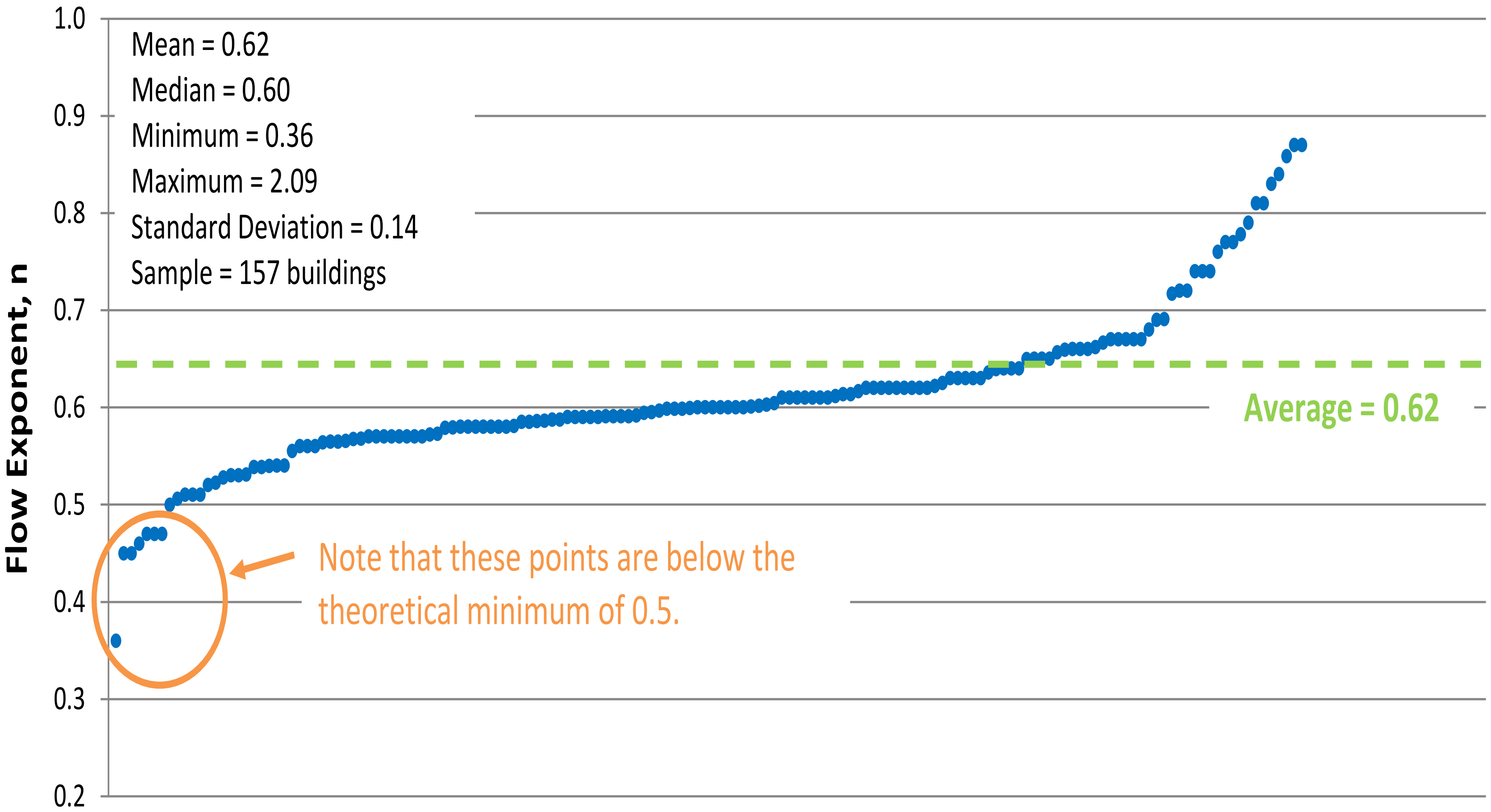
Flow Exponent



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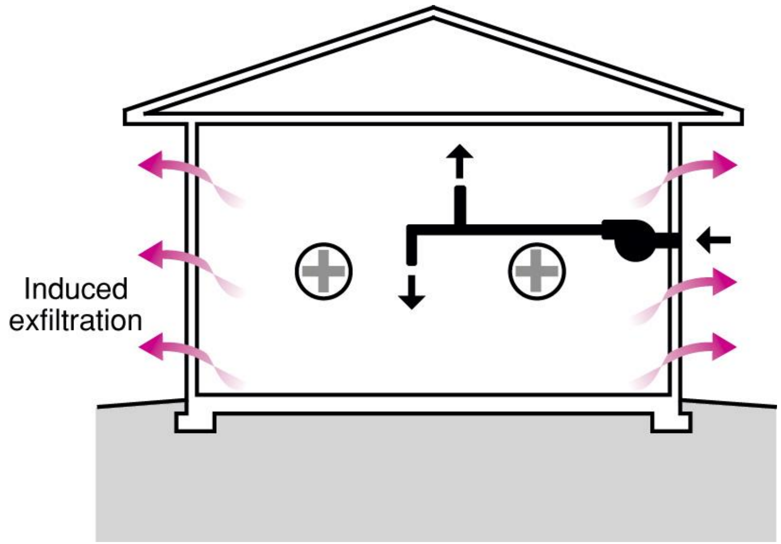
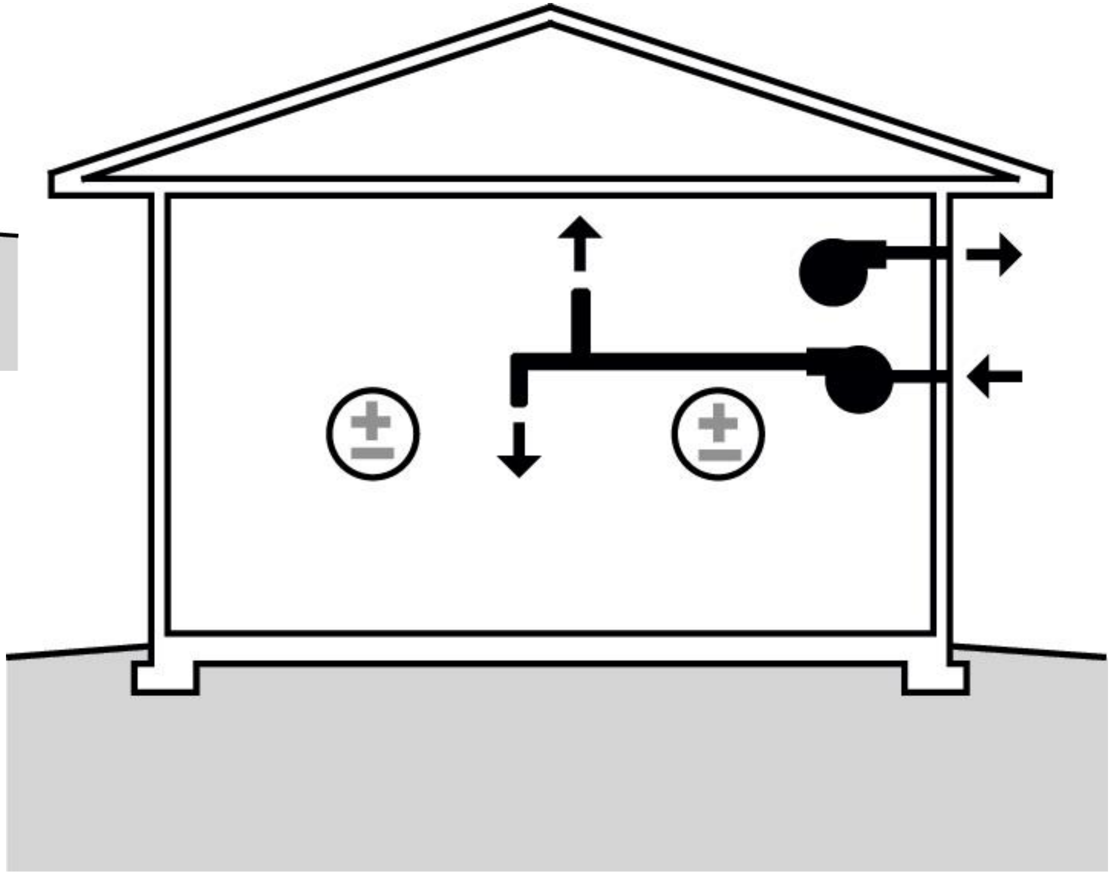
Enclosure – HVAC interaction

- Without estimate of airtightness:
  - How to size equipment?
  - How to predict energy use?
- Pressurization / depressurization
  - Significant operational implications

- Old buildings were leaky and this did not matter ….

Commercial HVAC





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