AIR FLOW DIAGNOSTICS AND RESNET STANDARDS

BERKELEY LAB
Lawrence Berkeley National Laboratory

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RESNET 2015

What is Standard 380?

- Brings together diagnostic tests related to building air flow (much of which is in existing Chapter 8):
  - Envelope leakage
  - Duct leakage
  - Mechanical ventilation
- Allows multiple test procedures for flexibility
- All single-family, but 3-story or less in MF
- "These standards are intended for use by home energy raters, energy auditors, or code officials to evaluate the performance of residential buildings."

Why a new standard?

1. Existing standards are not quite right for RESNET
   - Change of focus – More detail on envelope and HVAC preparation, less on other details, e.g., extra measurements ensuring pressure uniformity
   - More metrics – we want to use CFM50, ACH50, NLA, SLA & ELA
   - Different applications and how to use test results
     - Energy rating vs. minimum compliance
2. No existing standard for ventilation air flows
   - could be referred to by ASHRAE 62.2
3. Gives step-by-step instructions for easier training and consistency

Envelope Leakage Test Methods

- Single point pressurization or depressurization of the building envelope to 50 Pa
- Multi point pressurization or depressurization of the building envelope from 10 to 60 Pa
  - Uses calculation procedure from ASTM E779-10

Envelope Preparation – some details about holes….

- **Non-motorized dampers** shall be **left in their as-found positions**. For example, a fixed damper in a duct supplying outdoor air for an intermittent ventilation system that utilizes the HVAC fan shall be left in its as-found position.
- **Motorized dampers** shall be **placed in their closed positions and shall not be further sealed.**
- Non-dampered ventilation openings of *intermittently* operating **local exhaust ventilation systems** (e.g., bath fan, kitchen range fan) shall be **left open.**
- Non-dampered ventilation openings of *intermittently* operating **whole-house ventilation systems**, including HVAC fan-integrated outdoor air inlets **shall not be sealed.**
- Non-dampered ventilation openings of *continuously* operating **whole-house ventilation systems shall be sealed**

More house preparation

- Normally: attic access closed, basement doors open, BUT……
- If an attic is air sealed and insulated at the roof deck:
  - Access doors shall be opened
  - The volume of the attic spaces shall be added to the conditioned space volume used in ratings and HERS
- If the basement is air sealed and insulated at the basement ceiling:
  - Access doors shall be closed
  - The volume of the attic spaces shall not be included in the conditioned space volume used in ratings and HERS

Envelope Leakage – Single Point

- Pressurize or depressurize to 50 Pa
- Corrections for not reaching 50 Pa

$$CFM50\ \left(\frac{ft^3}{min}\right) = Q_{high}\left(\frac{ft^3}{min}\right)\left(\frac{50}{dP_{high}}\right)^{0.65}$$

- Altitude and temperature corrections from ASTM E779-10: <u>software allowed</u>

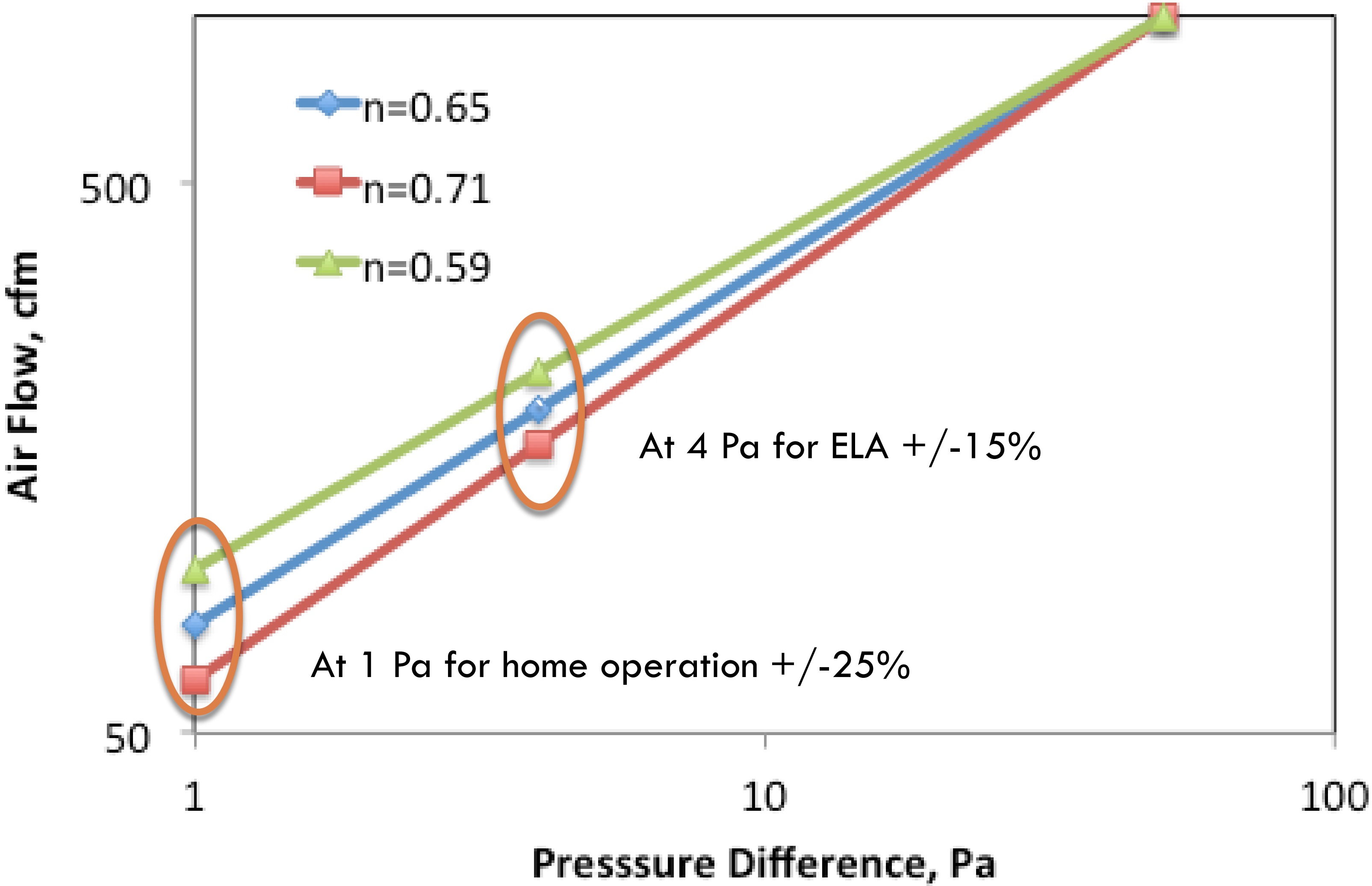
$$ELA(in^2) = \frac{Corrected\ CFM50}{18.2}$$

Multipoint Envelope Leakage

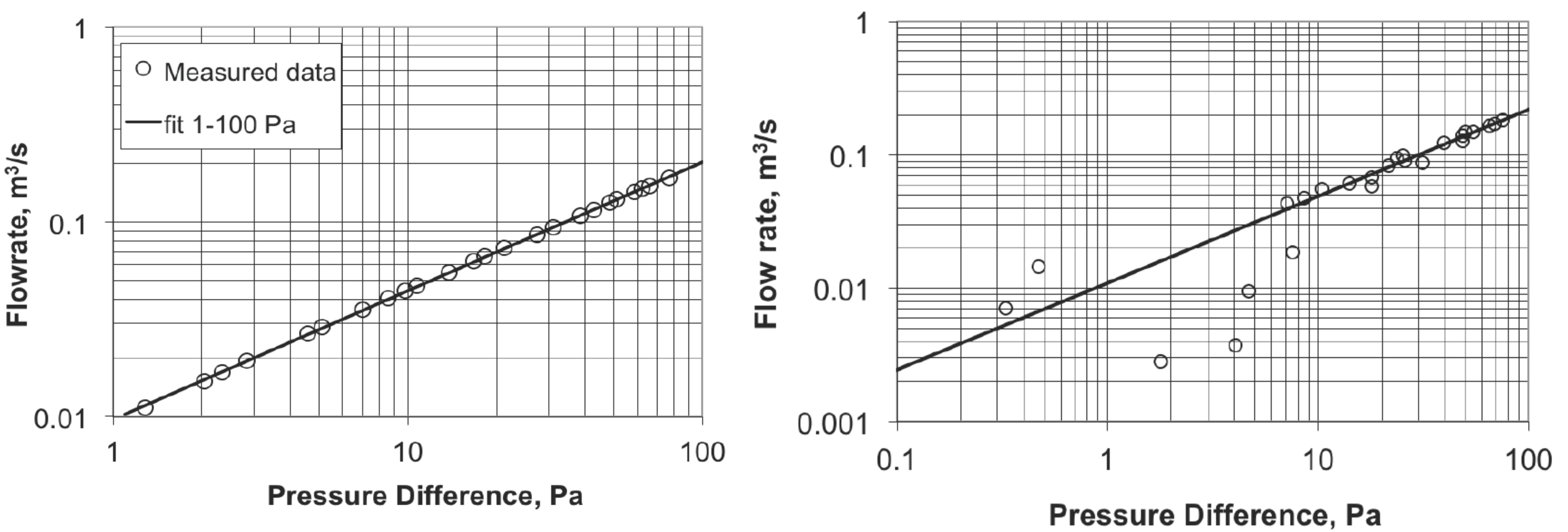
- 10 -60 Pa pressure range
- Same Altitude and temperature corrections
- Fit to: $Q = C(dP)^n$ using methods in ASTM E779-10: <u>software allowed</u>

$$ELA(in^2) = C\left(\frac{ft^3}{minPa^n}\right) \times 0.567 \times 4^{(n-0.5)}$$

Envelope Leakage Test Issues: Single Point - extrapolation



Envelope Leakage Test Issues: Multipoint – windy days



Strong function of windspeed: errors small < 12 mph
Compromise ~ 10%
Overall ~ 10% better than single point

Correcting for test uncertainty

- For retrofit energy savings, conducting an energy audit, or assessing the relative enclosure air leakage of a group of buildings, then no further corrections are made
- For a home energy rating or compliance with enclosure leakage limit we account for extrapolation to operating conditions:
  - Single Point:

Adjusted CFM50 = 1.1 x CFM50

Adjusted ELA = 1.1 x ELA

Conversions to other metrics

- ACH50 = CFM50 x 60 / Building Volume in cubic feet
  - Used in IECC requirements
- SLA = 0.00694 x ELA in in^2 / Building Floor Area in square feet
  - Used in RESNET Standard and CA T24
- NLA = SLA x $(S)^{0.4}$, where S is the number of stories above grade
  - Used in ASHRAE 62.2 for infiltration credit

Duct Leakage Test Methods

- Duct Leakage pressurization or depressurization to 25 Pa
  - Total duct leakage or
  - Leakage to outside by pressurizing or depressurizing the house to the same test pressure
  - Does not separate supply from return
  - Includes provisions for “can’t reach 25”
- For Air Leakage at operating conditions: Test method A of ASTM E1554 (DeltaQ)

Total Duct Leakage – System Preparation

- All zone and bypass dampers shall be set to their open position to allow uniform pressures throughout the duct system
- All balancing dampers shall be left in their as-found position
- Non-dampered ventilation openings are sealed if continuous and open if intermittent
- You may remove registers atop carpets and seal the face of the duct boot

Total duct leakage

- Exterior access panels open for unconditioned spaces containing ducts
- Duct leak tester may be attached at return grille or blower access panel
- Several options for duct pressure location (must be recorded)
- Pressurize house to 25 Pa
- Zero pressure between house and ducts

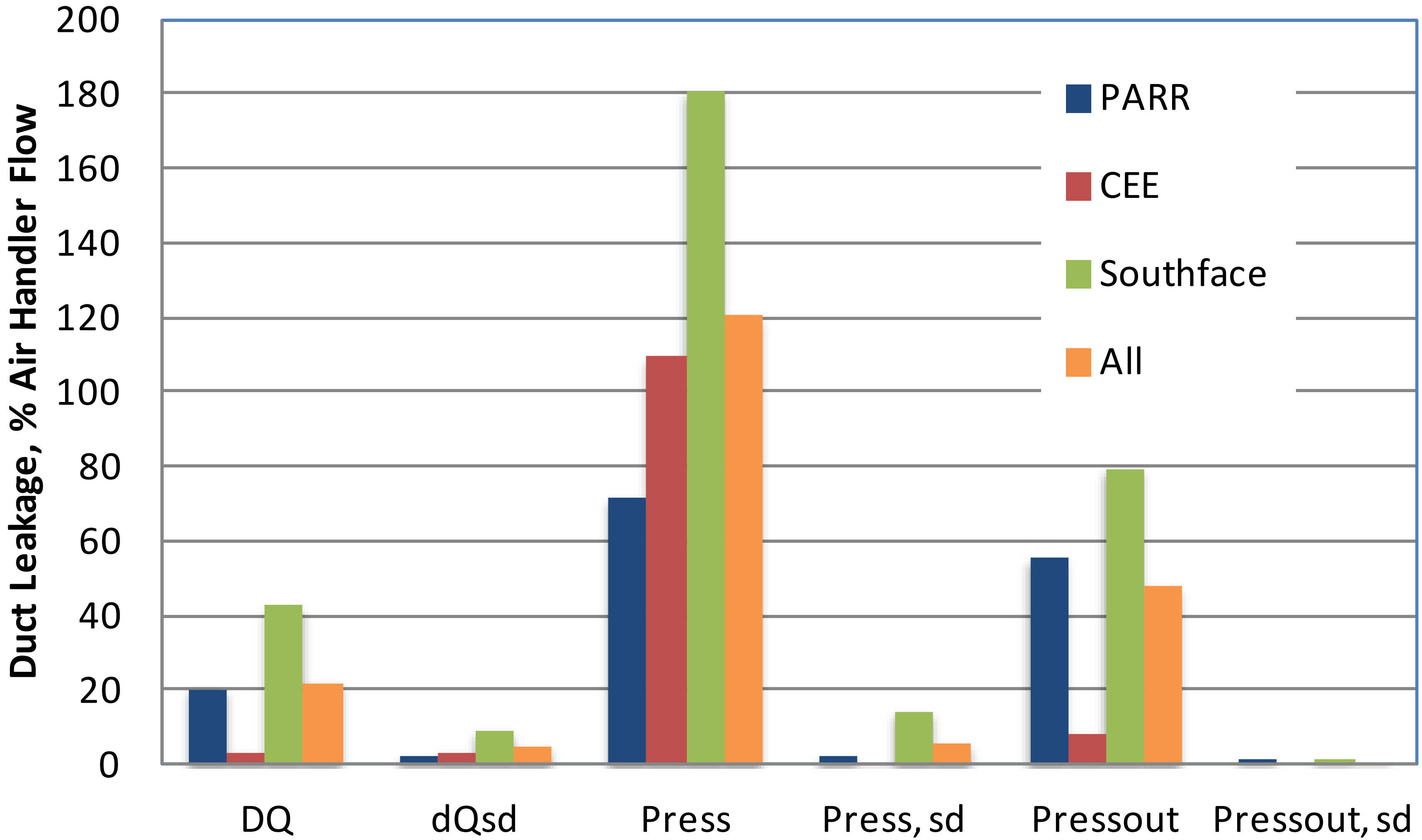
Duct Leakage Applications

- For compliance with a total duct leakage limit use total duct leakage
- For compliance with a leakage to outside limit use either total or leakage to outside
- For use in an energy audit or prediction of energy savings use leakage to outside

Duct Leakage Performance Issues

- Some duct systems have no attempt at sealing (northern tier basements in particular) and have nonsensical pressurization results
- On very windy days DeltaQ testing is unreliable
- What about repeatability?
  - Recent study on 30 homes by Building America
  - All three tests repeated continuously for a day – about ten repeats – so about 900 total tests

Test results – average and standard deviations

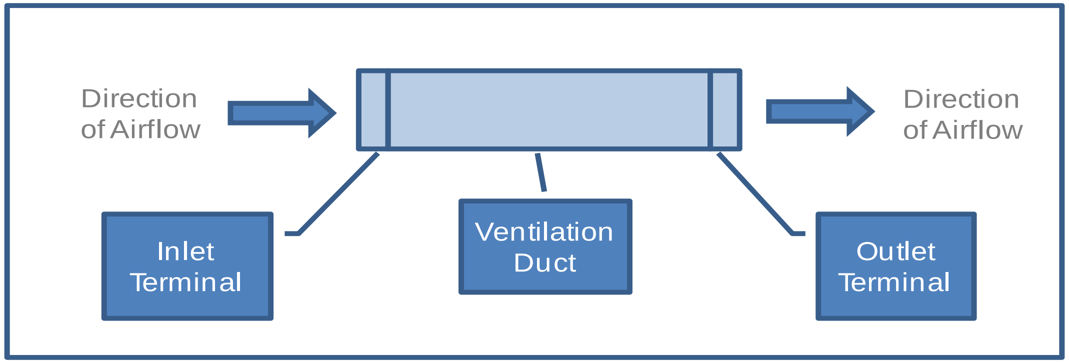


Repeatability results

- For DeltaQ and Total Pressurization: +/- 6%
- For Pressurization to outside: +/- 1%
- For low leak (<6% by DeltaQ) systems much better repeatability:
  - Pressurization: +/- 1% (800 cfm)
  - Pressurization to outside: +/- 0.3% (115 cfm)
  - DeltaQ: +/- 3% (30 cfm)

Ventilation Air Flow Test Methods in RESNET 380

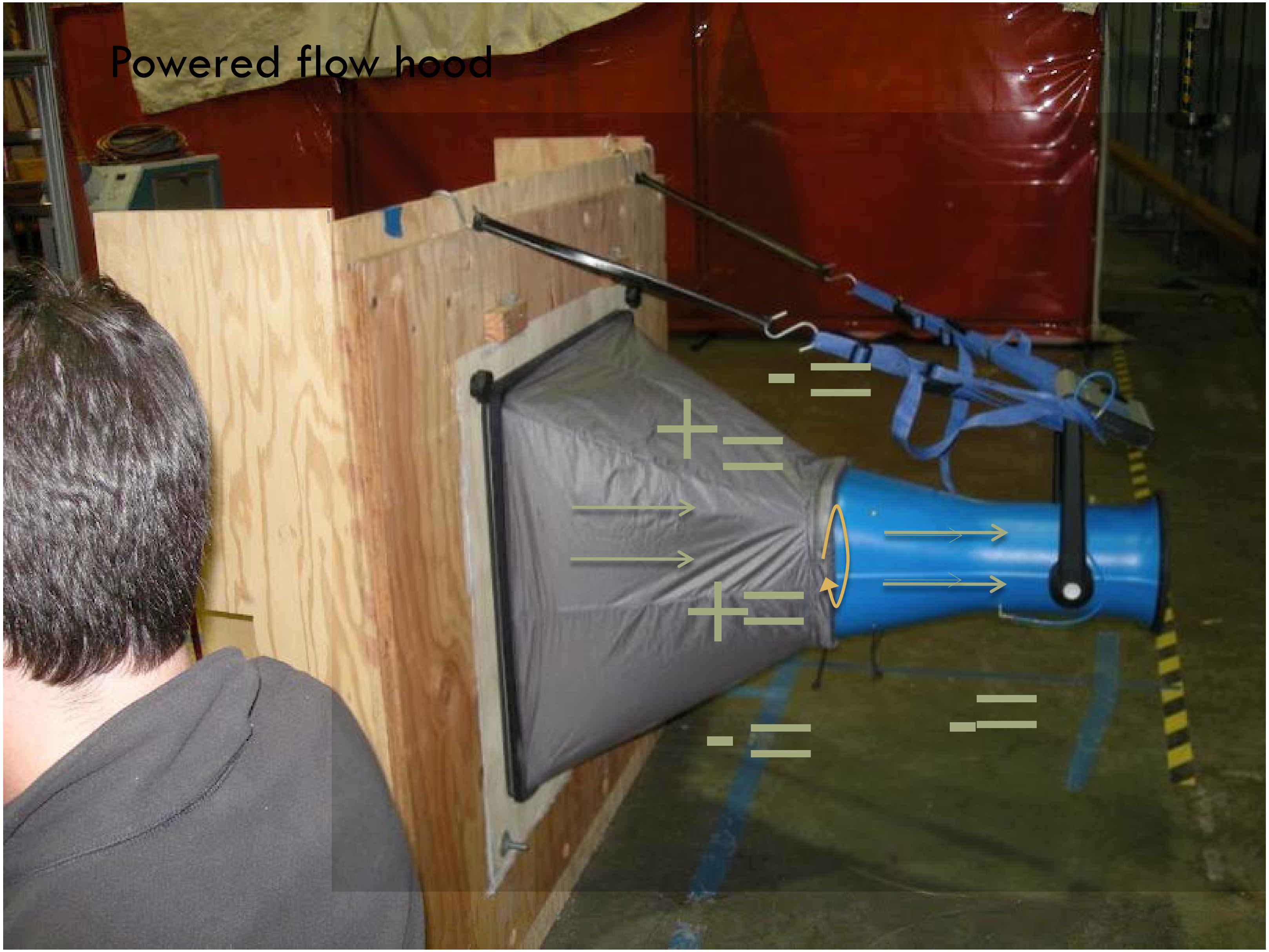
- Airflow at inlet
  - Powered flow hood
  - Air flow resistance
  - Passive flow hood
- Airflow at outlet
  - Powered flow hood
  - Bag inflation
- In-duct airflow
  - Flow measurement station



Flow at Inlet or Outlet terminal

- Powered flow hood
  - Fan zeros pressure between capture hood and room
  - Can be commercial devices or build your own

Powered flow hood



Flow at Inlet Terminal

- Air flow resistance
  - Single branch only!!!!!
  - Known air flow resistance: measure pressure difference
  - If you know opening area (square inches) and pressure difference (Pa), you can build your own and use:

$$Airflow\ (CFM) = Opening\ Area\ x\ 1.07\ x\ (dP)^{0.5}$$

Flow at Inlet Terminal

- Passive flow hood
- Only if pressure difference between hood and room < 5 Pa
  - Many commercially available devices are not precise or accurate enough at ventilation air flow rates (e.g., < 50 cfm)

Flow at Outlet Terminal – Bag Inflation

- If you know volume (gallons) and time (seconds)

Airflow (CFM)=(8 × Volume)/(Elapsed Time)

Flow at Outlet Terminal – Bag Inflation

ABOUT YOUR HOUSE

CE33

CMHC GARBAGE BAG AIRFLOW TEST

There are times when you need to know the airflow from your furnace registers, bathroom exhaust fan or clothes dryer exhaust.

For example, if a house has one cold room in the winter, it is useful to find out if this is because your furnace isn't supplying enough warm air. If you installed a new bathroom exhaust fan, you could use the test to see if it is working properly.

This publication tells you how to do the *CMHC Garbage Bag Airflow Test*. The Test is a quick way to estimate airflow, by determining how long it takes to fill a common plastic garbage bag.

It is not a precise measurement, but it is a vast improvement over no measurement at all.

How to do the test

Here's how to use the test to measure airflow from a register or exhaust:

- Tape the mouth of the garbage bag to a bent coat hanger or a piece of cardboard to keep it open. (See Figure 1)
- Crush the bag flat.
- Place it over the register or exhaust hood.
- Count how many seconds it takes for the bag to inflate. (See Figure 2)
- Find the airflow from the register or exhaust from one of the following tables.

If you want to measure air going out, you can hold an inflated bag against an exhaust grill, and count how many seconds it takes for the bag to deflate. Deflation testing is not as accurate as inflation testing, but it is still a reasonable test. Low airflow is difficult to measure by deflation testing.

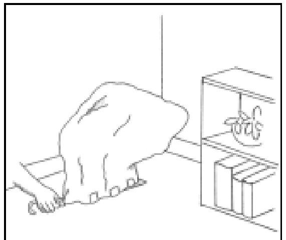


Figure 2

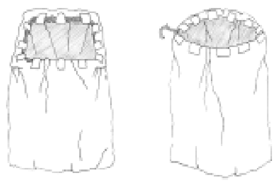


Figure 1

CMHC SCHL

HOME TO CANADIANS

Canada

Small green garbage bag (Glad 66 x 91 cm)

Time to inflate	Flow of air into the bag
2 seconds	35 L/s (75 cfm)*
4 seconds	20 L/s (40 cfm)
10 seconds	10 L/s (20 cfm)

* L/s = litres per second; cfm = cubic feet a minute

For deflation, add a second. Therefore, 35 L/s would take about three seconds and 20 L/s about five seconds.

Big orange garbage bag (Glad 79 x 119 cm)

Time to inflate	Flow of air into the bag
2 seconds	100 L/s (210 cfm)*
4 seconds	50 L/s (105 cfm)
6 seconds	35 L/s (75 cfm)
10 seconds	20 L/s (40 cfm)

* L/s = litres per second; cfm = cubic feet a minute

Deflation times for the big orange bag are about the same as inflation times.

How to use the test

Using the examples mentioned above, if the measured airflow from a forced-air register is less than 10 L/s, the furnace is delivering only a small amount of heat to a room.

If you install a 100 cfm exhaust fan, and the fan inflates a standard bag in less than two seconds, you have the rated exhaust flow for the fan.

CMHC's Garbage Bag Airflow Test is also useful if you have changed your heating or cooling systems, or if you have made major renovations to your house.

To find more *About Your House* fact sheets plus a wide variety of information products, visit our Web site at

www.cmhc-schl.gc.ca

or contact:

Your local CMHC office
or
Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa ON K1A 0P7

Phone: 1 800 668-2642
Fax: 1 800 245-9274

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Produced by CMHC

02-01

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Sometimes bag inflation is the only way?

Flow at Outlet Terminal

In-Duct Air Flows

- Requires air flow measurement station in duct
- Can be permanent or temporary installation
- Air flow derived from converting pressure to average air velocity, V (fpm), and multiplying by cross-sectional area, A (ft^2):

$$\text{Airflow (CFM)} = V \times A$$

Current Status of RESNET 380

- Soon to have 2nd public review – ONLY of things that changed from first pubic review
- Please read and comment – go to RESNET website

Measuring Single Branch Air Flows

- Heating, cooling, and ventilation systems
- 10-200 cfm
- Range of register sizes and configurations
- Inlet and outlet


ALNOR


ALNOR


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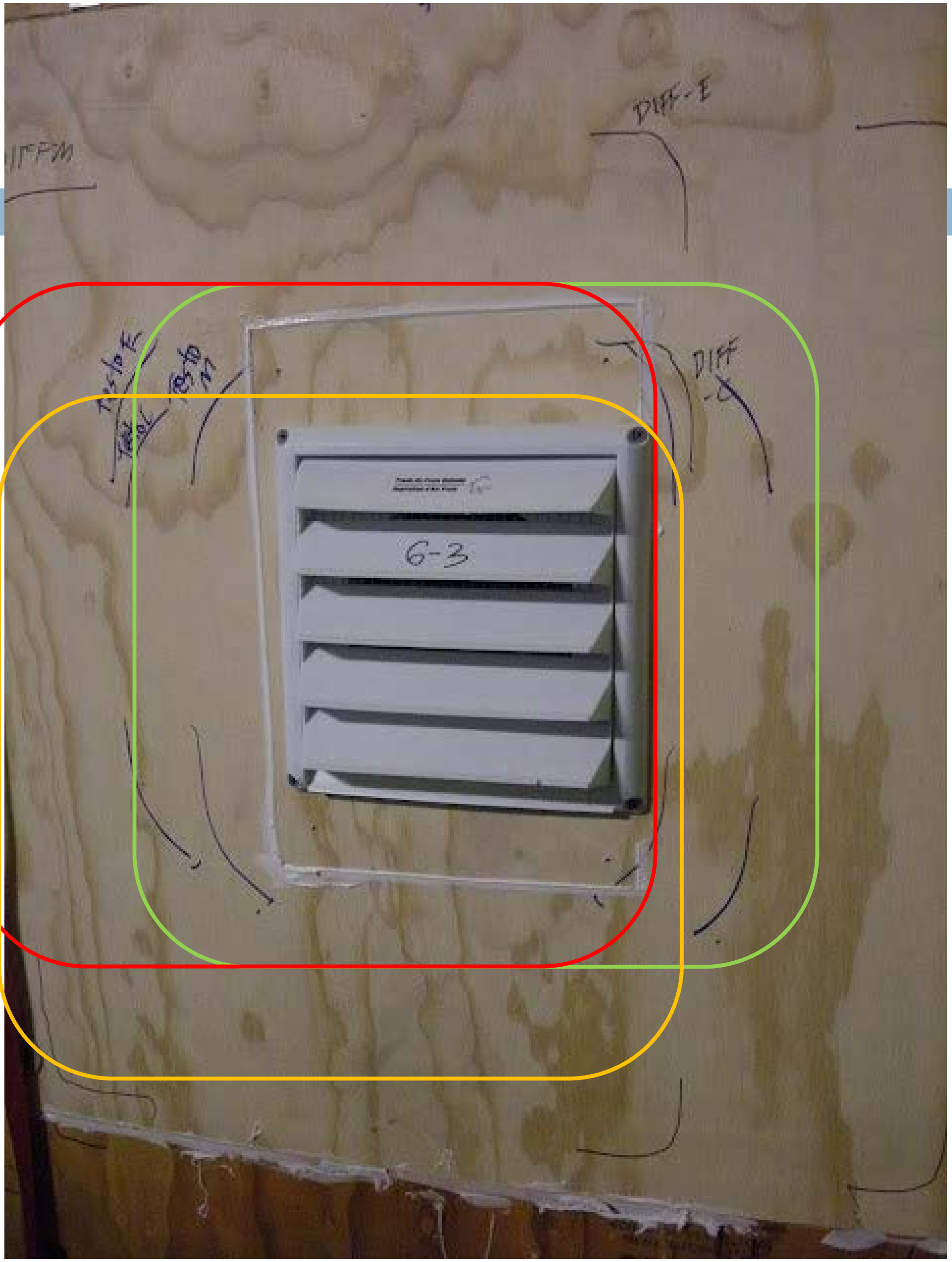
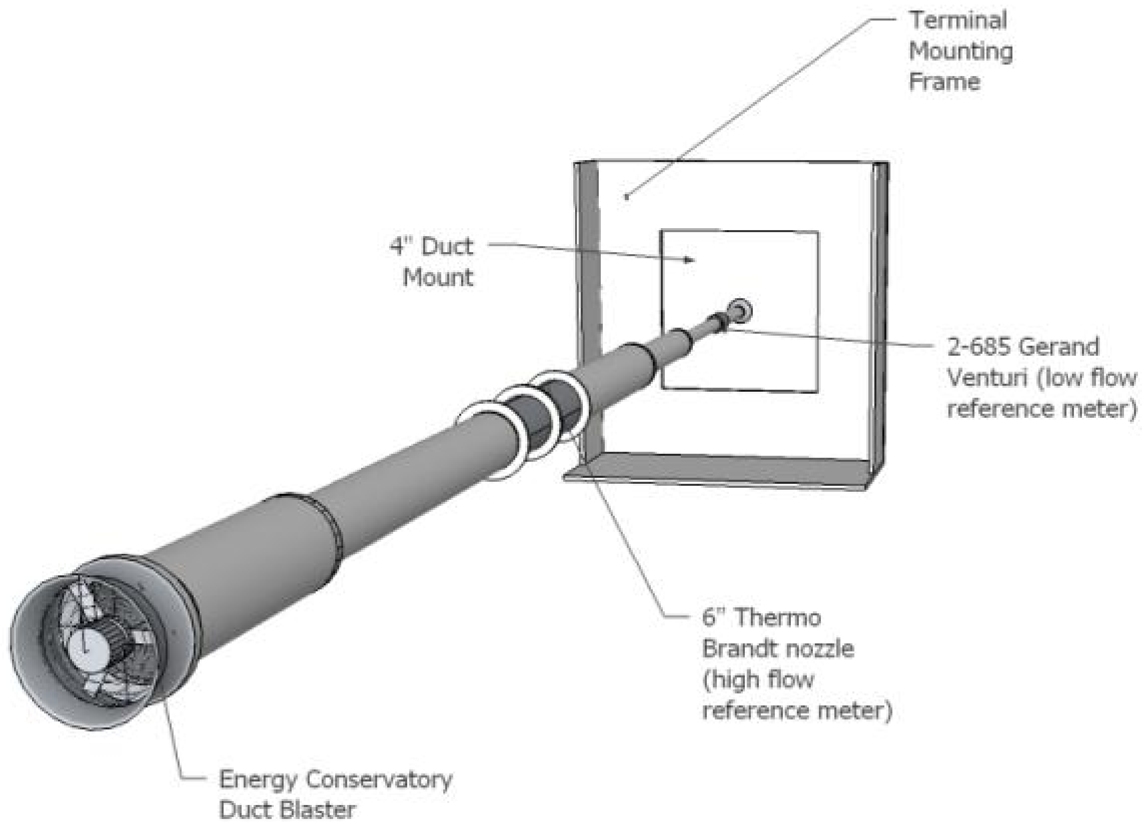
the testing process

- cruise at designated flows ("pressure stations" as measured by reference meter)
- correct for air density by measuring barometric pressure, temperature, relative humidity
- measure and correct for leakage after any change to the system

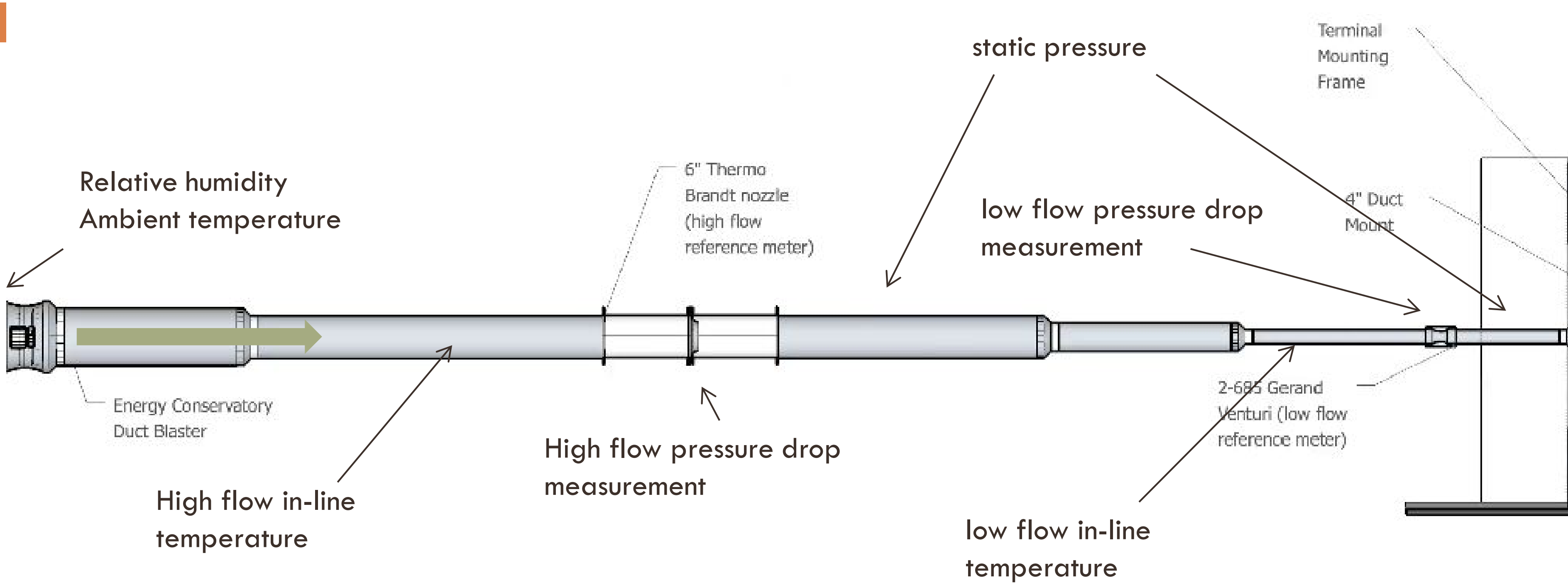


- middle
- edge
- corner

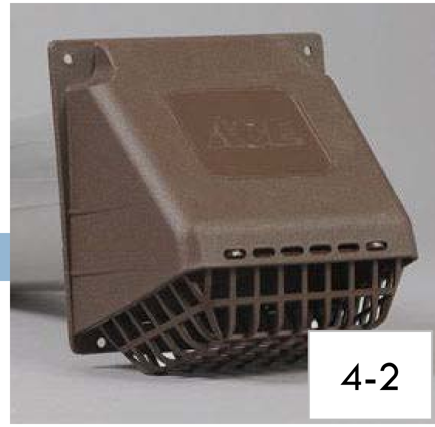
Airflow measurement apparatus



Airflow measurement apparatus



4-1



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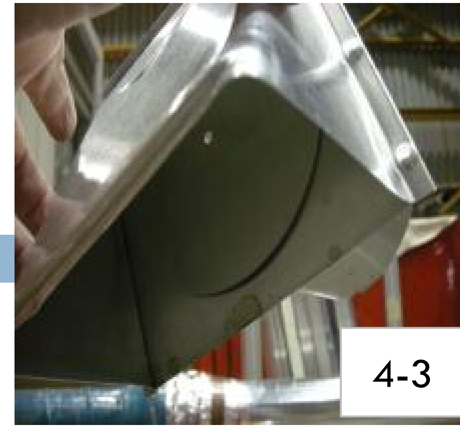

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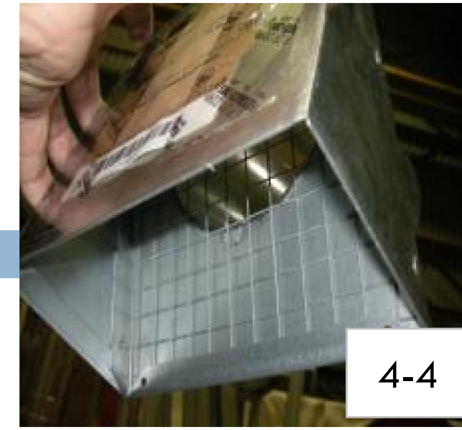
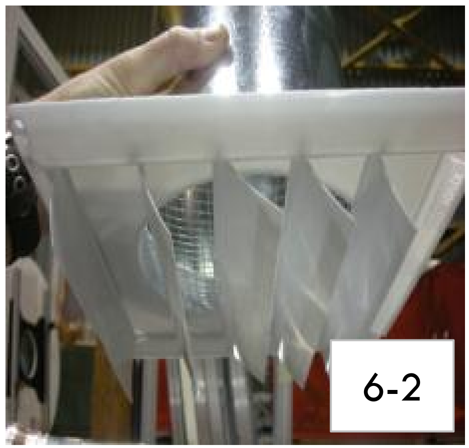


4-4

6-1



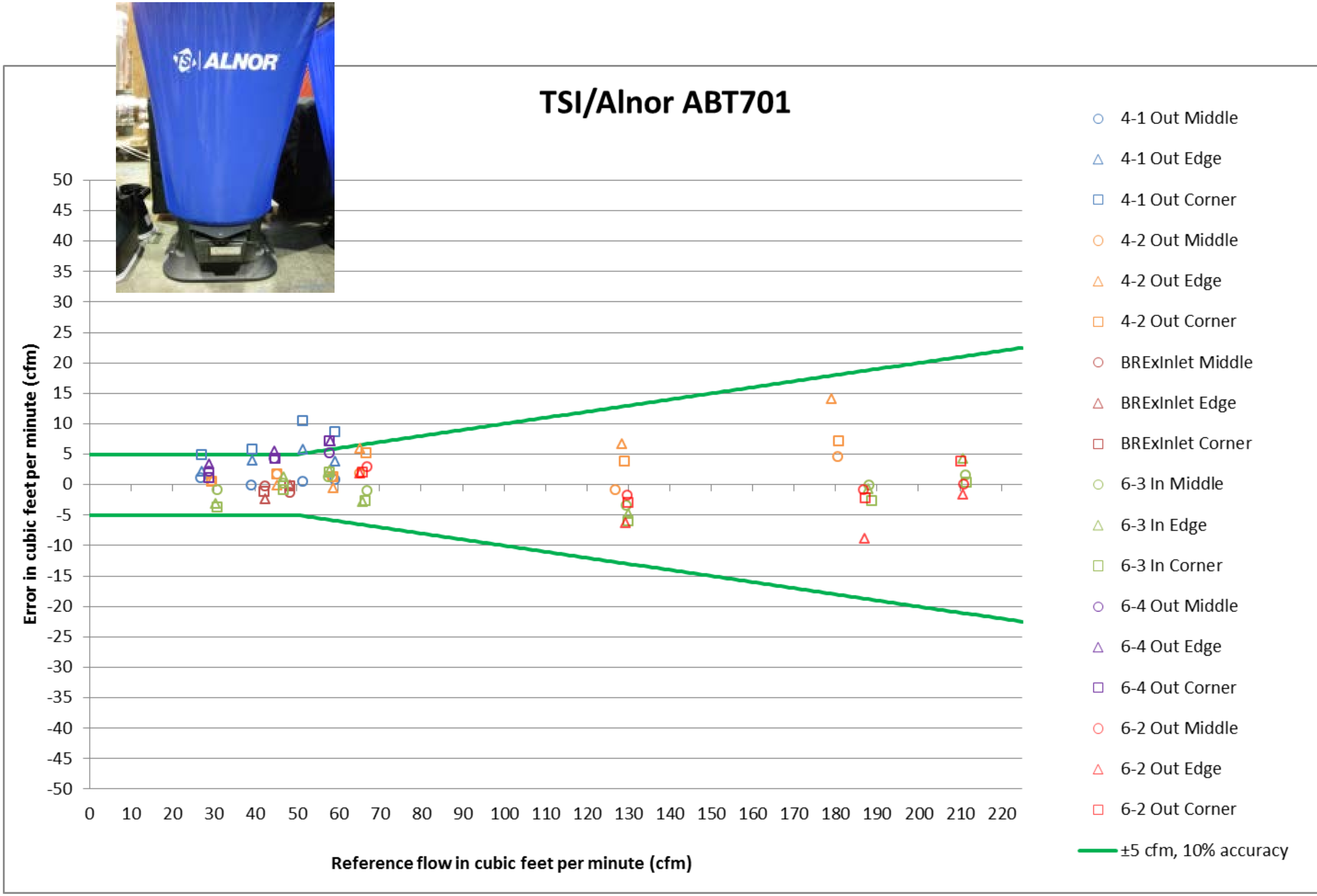
6-2

6-3

6-4

BRExInlet

BRExInlet


TSI/Alnor ABT701
ALNOR
Error in cubic feet per minute (cfm)
50
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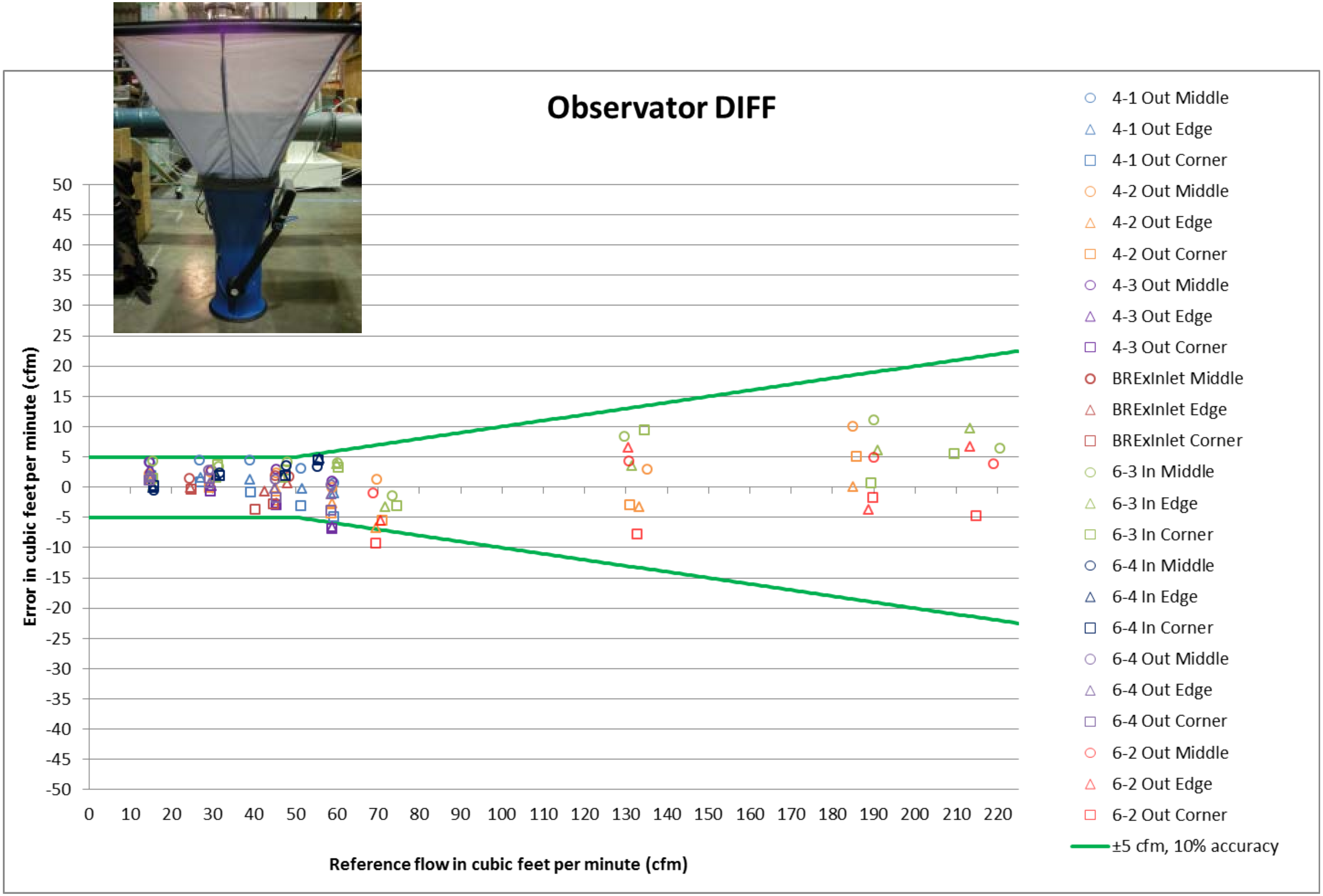
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220
Reference flow in cubic feet per minute (cfm)
4-1 Out Middle
4-1 Out Edge
4-1 Out Corner
4-2 Out Middle
4-2 Out Edge
4-2 Out Corner
BRExInlet Middle
BRExInlet Edge
BRExInlet Corner
6-3 In Middle
6-3 In Edge
6-3 In Corner
6-4 Out Middle
6-4 Out Edge
6-4 Out Corner
6-2 Out Middle
6-2 Out Edge
6-2 Out Corner
±5 cfm, 10% accuracy



Observator DIFF
Error in cubic feet per minute (cfm)
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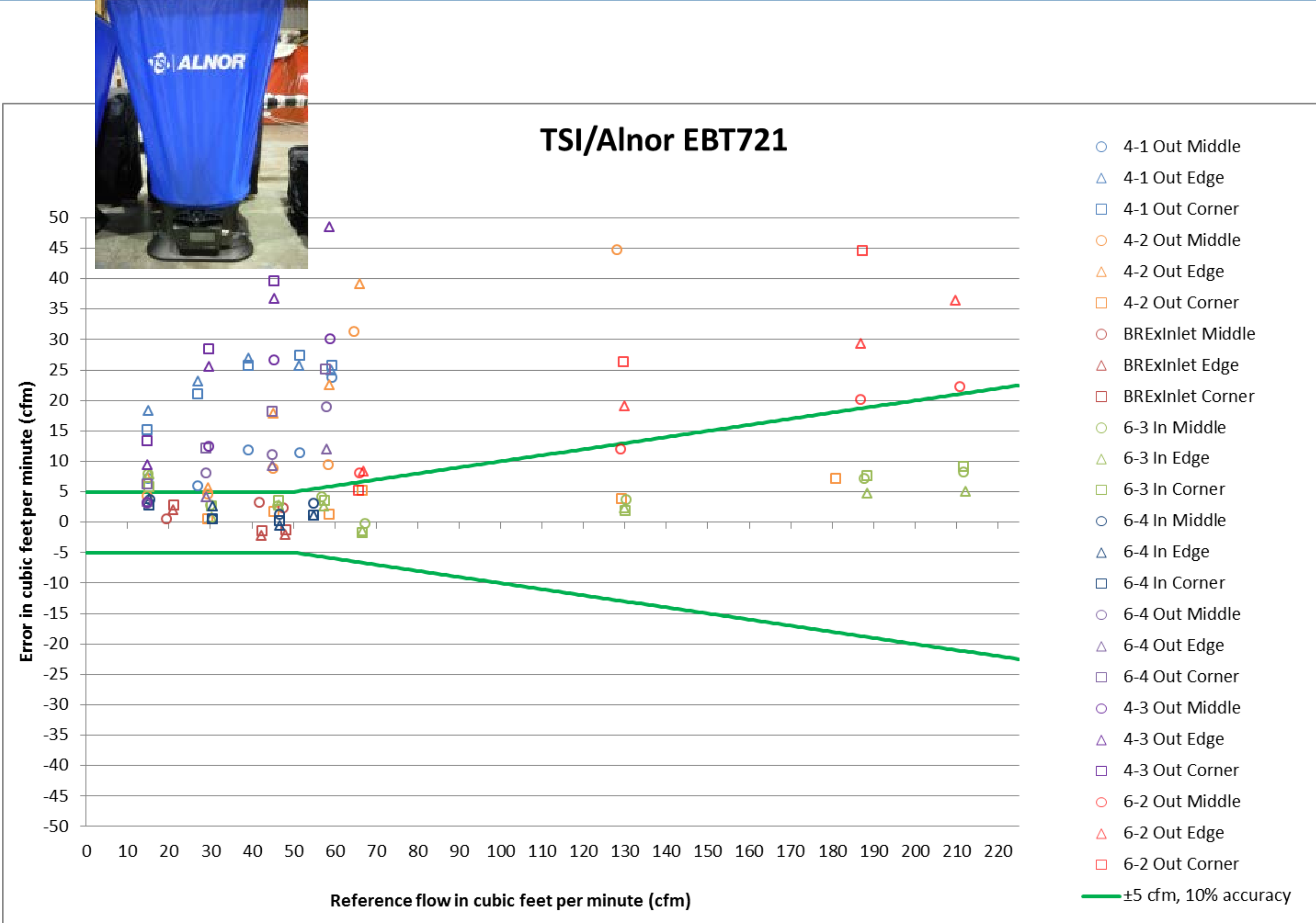
Reference flow in cubic feet per minute (cfm)
4-1 Out Middle
4-1 Out Edge
4-1 Out Corner
4-2 Out Middle
4-2 Out Edge
4-2 Out Corner
4-3 Out Middle
4-3 Out Edge
4-3 Out Corner
BRExInlet Middle
BRExInlet Edge
BRExInlet Corner
6-3 In Middle
6-3 In Edge
6-3 In Corner
6-4 In Middle
6-4 In Edge
6-4 In Corner
6-4 Out Middle
6-4 Out Edge
6-4 Out Corner
6-2 Out Middle
6-2 Out Edge
6-2 Out Corner
±5 cfm, 10% accuracy


ALNOR
TSI/Alnor EBT721
Error in cubic feet per minute (cfm)
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Reference flow in cubic feet per minute (cfm)
4-1 Out Middle
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4-2 Out Corner
BRExInlet Middle
BRExInlet Edge
BRExInlet Corner
6-3 In Middle
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6-4 In Middle
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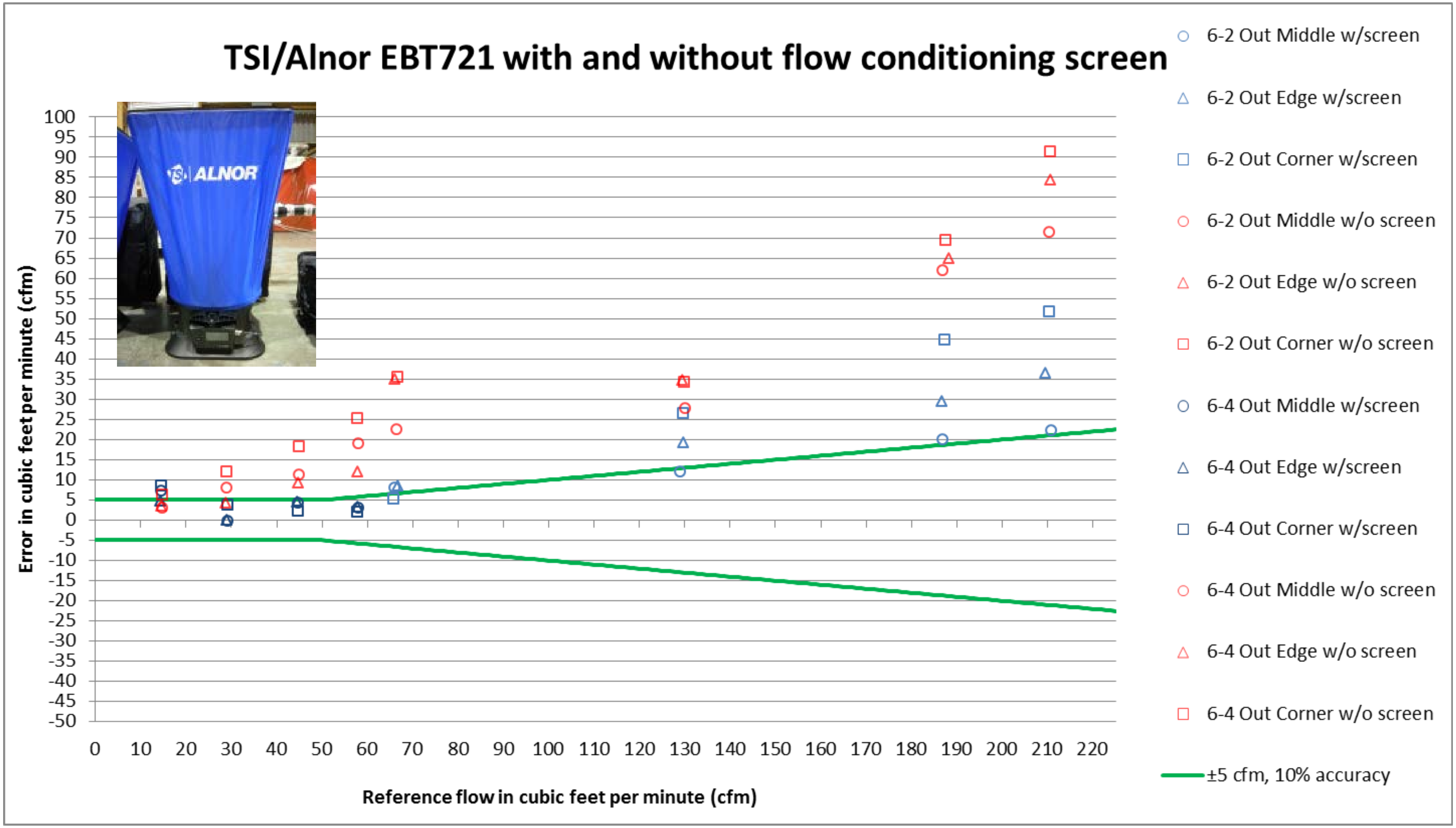
6-4 Out Corner
4-3 Out Middle
4-3 Out Edge
4-3 Out Corner
6-2 Out Middle
6-2 Out Edge
6-2 Out Corner
±5 cfm, 10% accuracy



TSI/Alnor EBT721 with and without flow conditioning screen
ALNOR
Error in cubic feet per minute (cfm)
Reference flow in cubic feet per minute (cfm)
100
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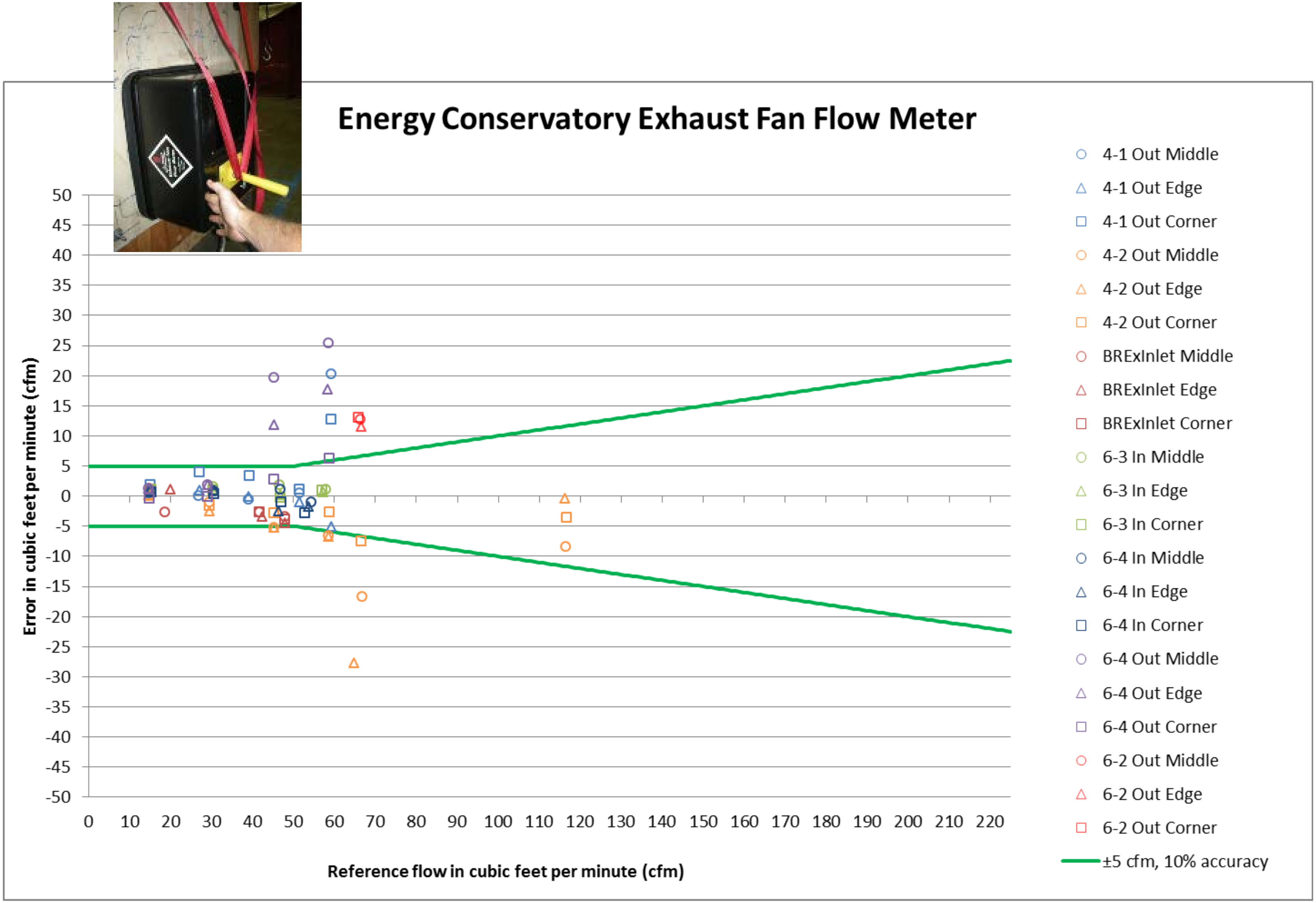
6-2 Out Middle w/screen
6-2 Out Edge w/screen
6-2 Out Corner w/screen
6-2 Out Middle w/o screen
6-2 Out Edge w/o screen
6-2 Out Corner w/o screen
6-4 Out Middle w/screen
6-4 Out Edge w/screen
6-4 Out Corner w/screen
6-4 Out Middle w/o screen
6-4 Out Edge w/o screen
6-4 Out Corner w/o screen
±5 cfm, 10% accuracy


Energy Conservatory Exhaust Fan Flow Meter
Error in cubic feet per minute (cfm)
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-25
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Reference flow in cubic feet per minute (cfm)
4-1 Out Middle
4-1 Out Edge
4-1 Out Corner
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4-2 Out Corner
BRExInlet Middle
BRExInlet Edge
BRExInlet Corner
6-3 In Middle
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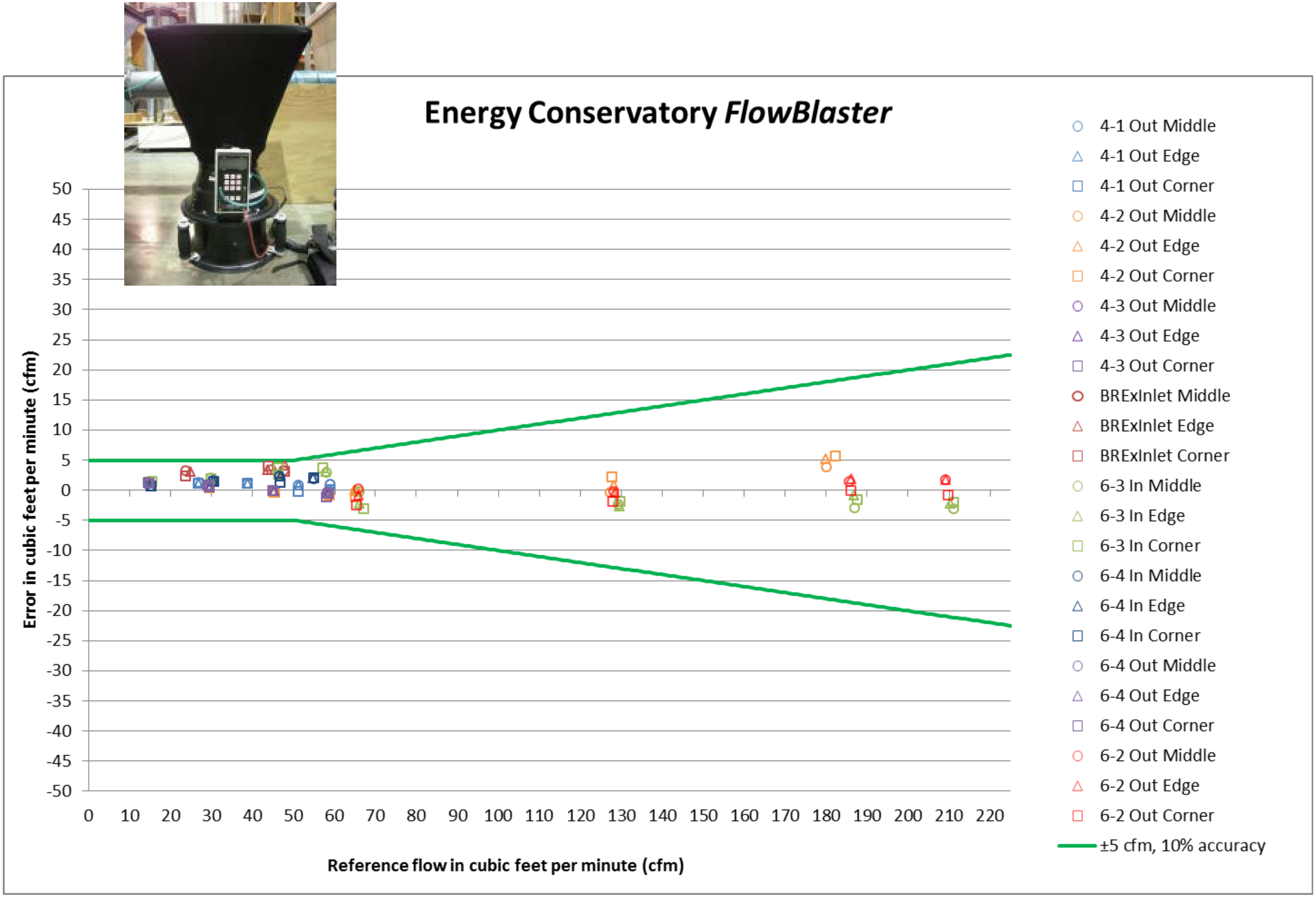
6-4 Out Corner
6-2 Out Middle
6-2 Out Edge
6-2 Out Corner
±5 cfm, 10% accuracy


Energy Conservatory FlowBlaster
Error in cubic feet per minute (cfm)
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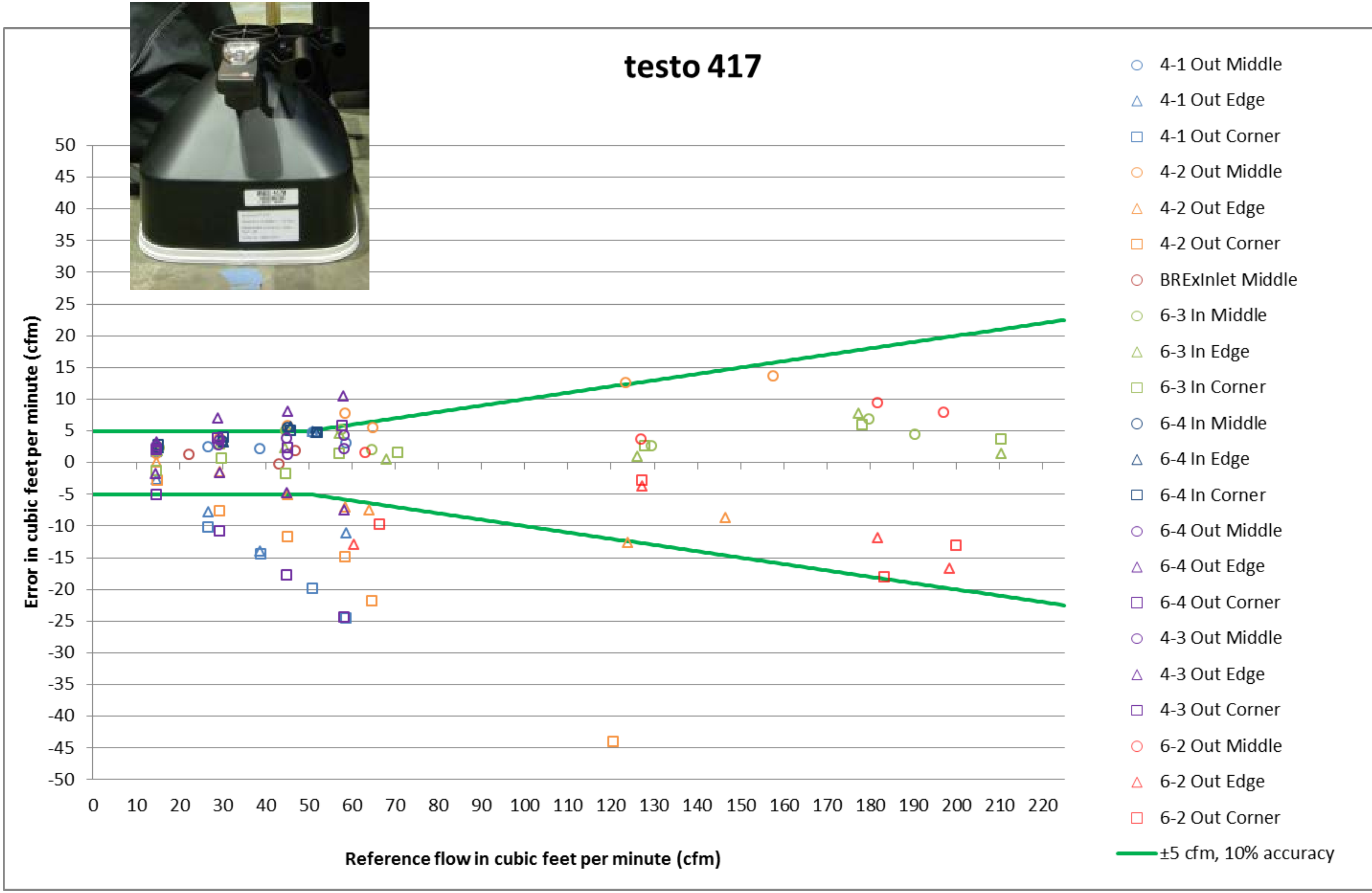
220
Reference flow in cubic feet per minute (cfm)
4-1 Out Middle
4-1 Out Edge
4-1 Out Corner
4-2 Out Middle
4-2 Out Edge
4-2 Out Corner
4-3 Out Middle
4-3 Out Edge
4-3 Out Corner
BRExInlet Middle
BRExInlet Edge
BRExInlet Corner
6-3 In Middle
6-3 In Edge
6-3 In Corner
6-4 In Middle
6-4 In Edge
6-4 In Corner
6-4 Out Middle
6-4 Out Edge
6-4 Out Corner
6-2 Out Middle
6-2 Out Edge
6-2 Out Corner
±5 cfm, 10% accuracy


testo 417
Error in cubic feet per minute (cfm)
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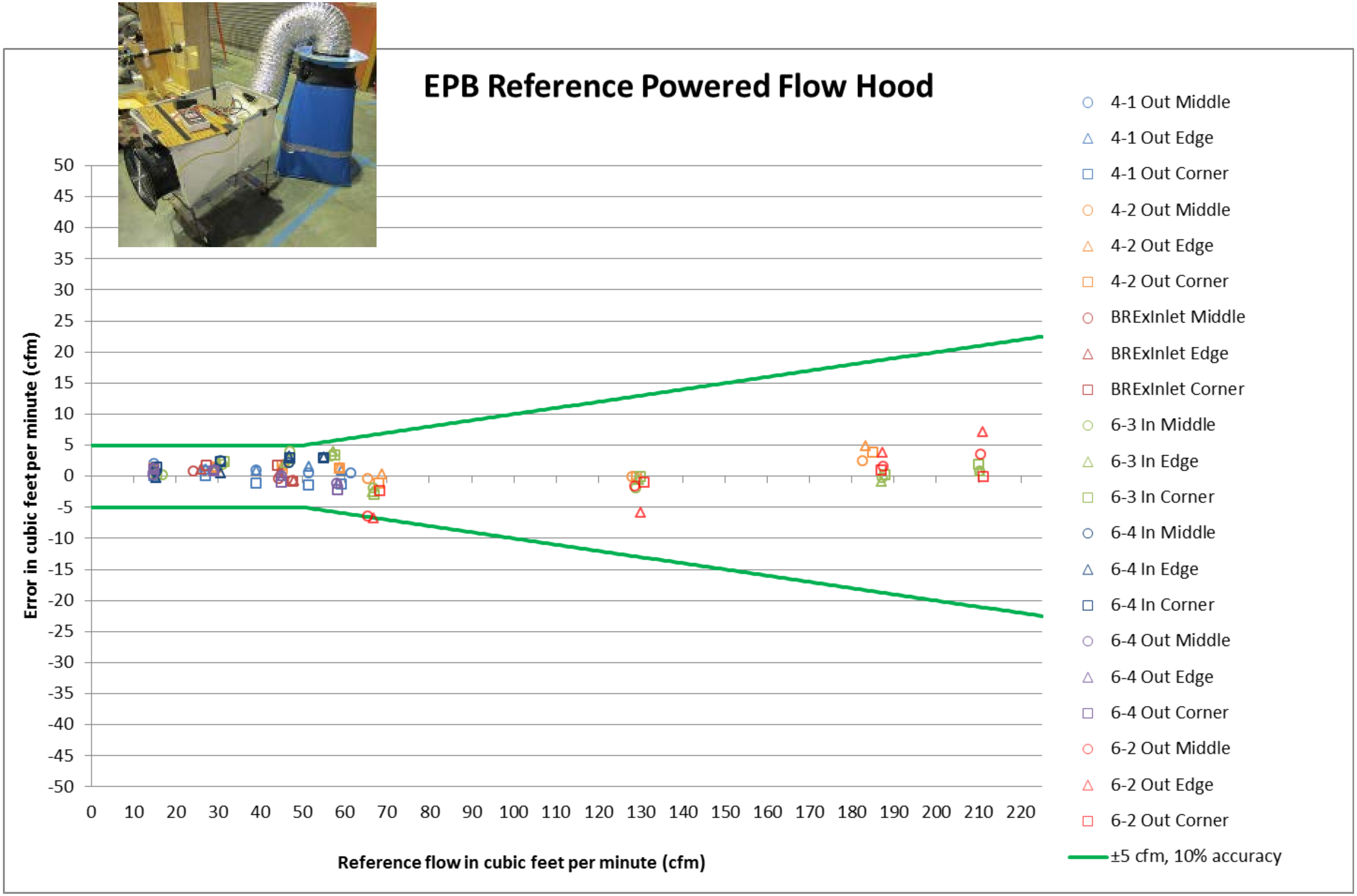
Reference flow in cubic feet per minute (cfm)
4-1 Out Middle
4-1 Out Edge
4-1 Out Corner
4-2 Out Middle
4-2 Out Edge
4-2 Out Corner
BRExInlet Middle
6-3 In Middle
6-3 In Edge
6-3 In Corner
6-4 In Middle
6-4 In Edge
6-4 In Corner
6-4 Out Middle
6-4 Out Edge
6-4 Out Corner
4-3 Out Middle
4-3 Out Edge
4-3 Out Corner
6-2 Out Middle
6-2 Out Edge
6-2 Out Corner
±5 cfm, 10% accuracy



EPB Reference Powered Flow Hood
Error in cubic feet per minute (cfm)
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-10
-15
-20
-25
-30
-35
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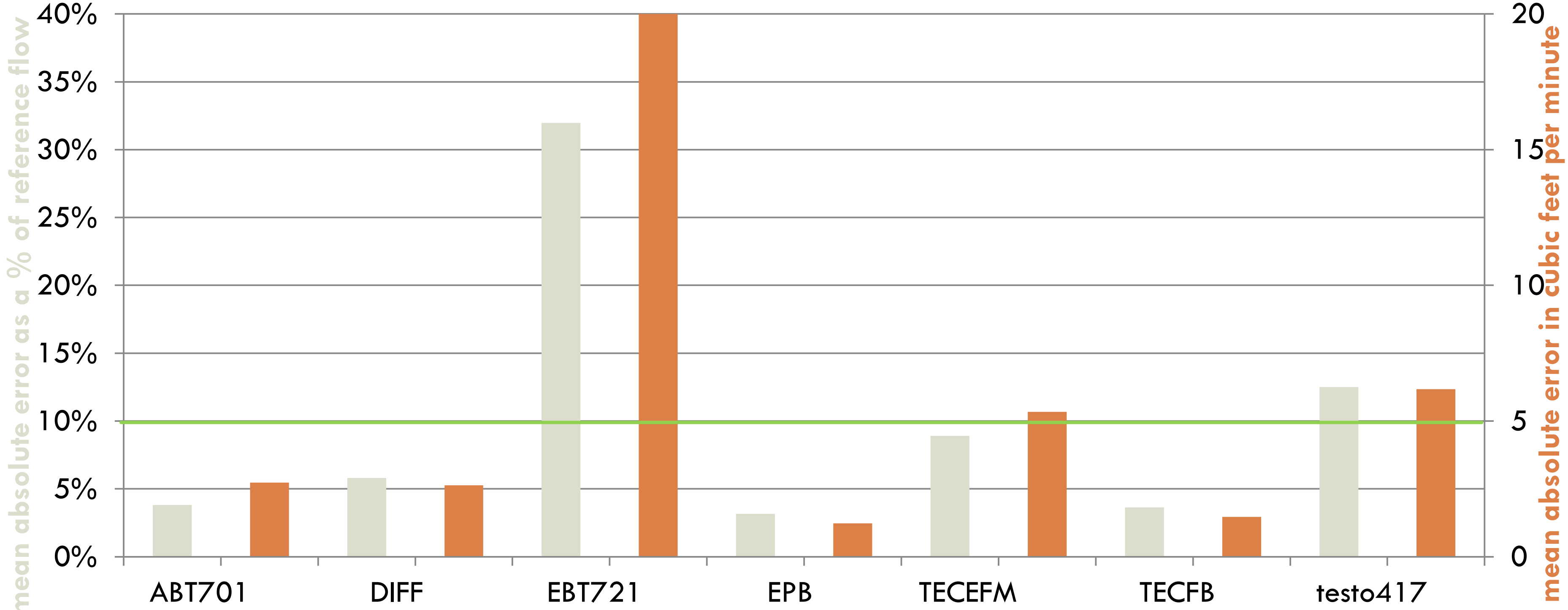
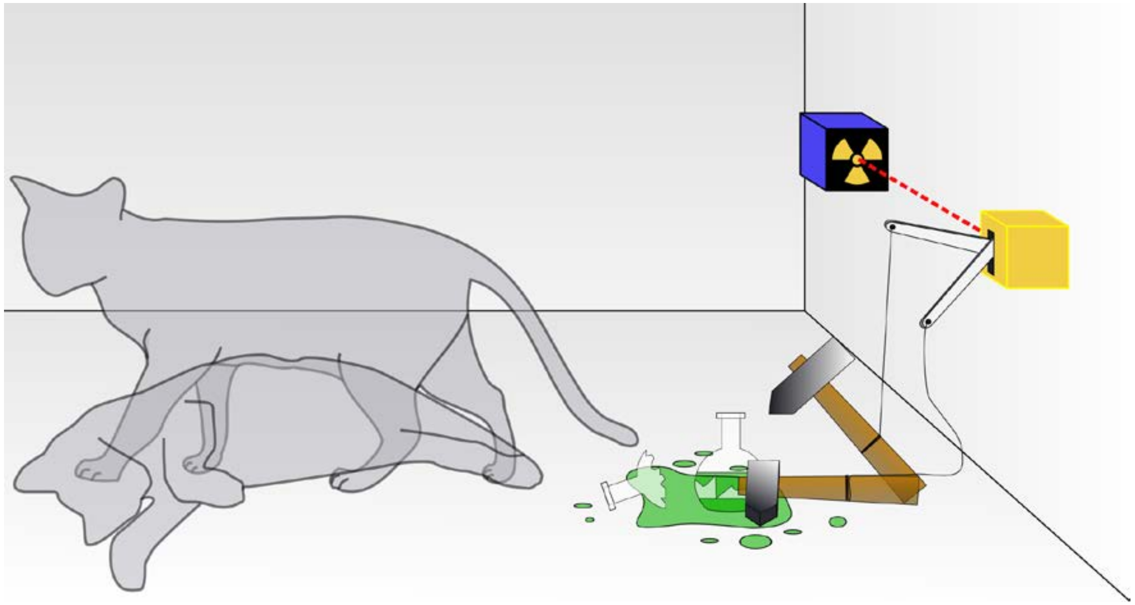
-50
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220
Reference flow in cubic feet per minute (cfm)
4-1 Out Middle
4-1 Out Edge
4-1 Out Corner
4-2 Out Middle
4-2 Out Edge
4-2 Out Corner
BRExInlet Middle
BRExInlet Edge
BRExInlet Corner
6-3 In Middle
6-3 In Edge
6-3 In Corner
6-4 In Middle
6-4 In Edge
6-4 In Corner
6-4 Out Middle
6-4 Out Edge
6-4 Out Corner
6-2 Out Middle
6-2 Out Edge
6-2 Out Corner
±5 cfm, 10% accuracy

Mean absolute error of all devices, for all flows

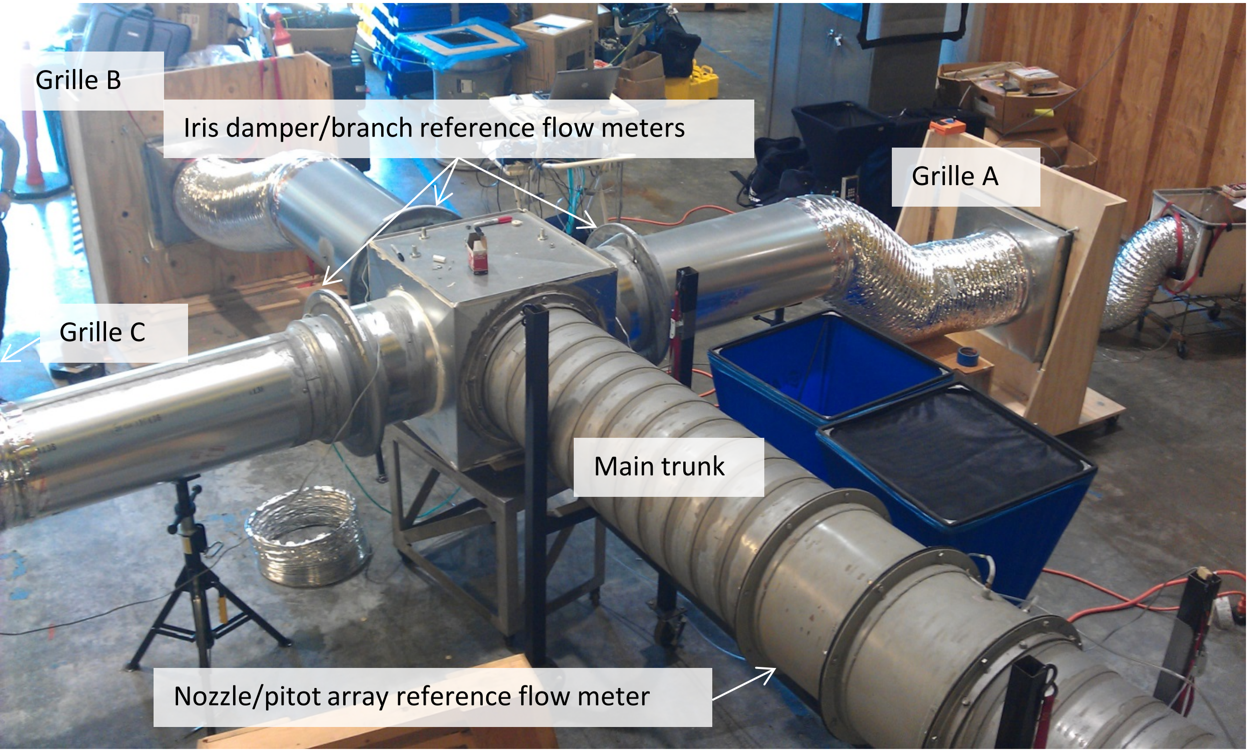


Recent study of return grill airflow measurement

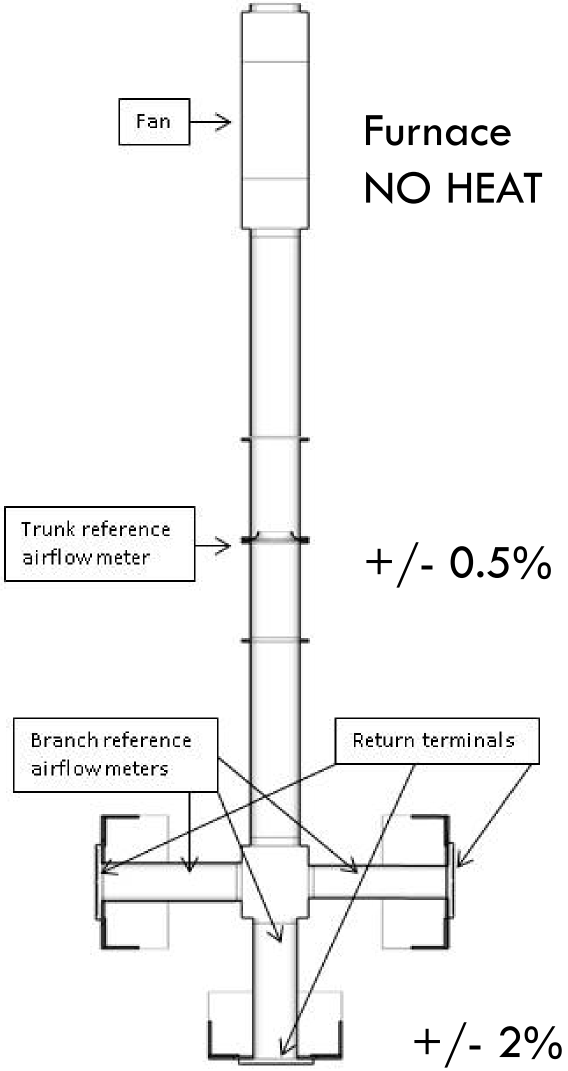
- CEC – wants to know what to say in Title 24
- Are some techniques/devices better than others?
- Multi. vs. single branch issues AKA Insertion Losses (Heisenberg?)



Laboratory Testing



Branch	Diameter (in.)	Pan Depth (in.)	Grille Dimensions (in. x in.)
A	16	4	24x24
B	16	4	20x20
C	14	4	14x24



Obsessive Air Sealing

- Less than 1% air leakage

Five Measurement Devices

ABT 701

EBT 721

testo 417

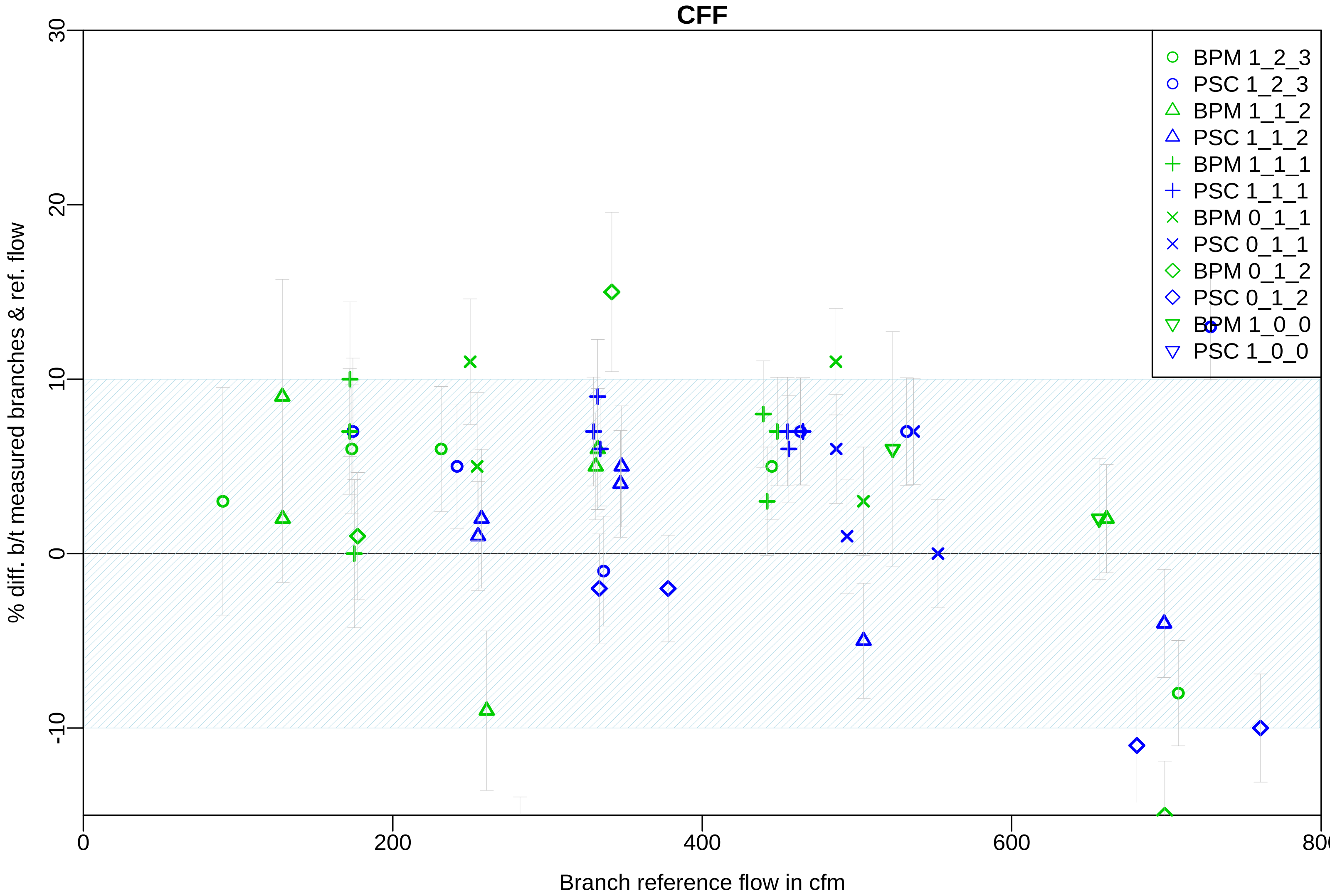
LBNL Hybrid

Cardboard + Fan/Flowmeter (CFF)

Test Configurations

- BPM and PSC blower motors
- Two motor speeds/airflows
- Six apparatus air flow configurations:
  - single branch,
  - two branches (with two different flow ratios between the branches), or
  - three branches (with three different flow ratios)

Example of individual branch measurement results: CFF



Instrument Error Summary

Mean – for a population of systems

RMS – for an individual system

	Individual Branch Air Flow, %		**Total System Air Flow, %**	
	Mean	RMS	Mean	RMS
ABT701	-2.8	4.8	-3.6	4.2
EBT721	9.3	10.1	9.6	10.1
LBNL Hybrid	7.5	10.1	6.3	7.7
CFF	2.5	7.5	1.7	5.7
Testo417	16.5	19.7	17.3	18.3

If +/-10% good enough then all but vane anemometer OK

Future Directions for Air Flow Measurement

- Developing ASTM test method to rate air flow devices
- Recommend use of powered flow hoods
- Revise testing standards to reduce uncertainty in measurements

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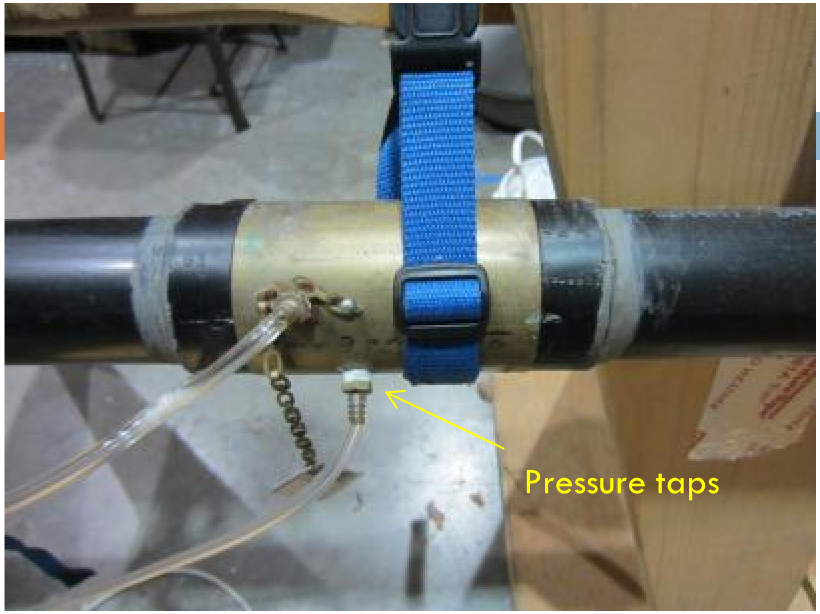
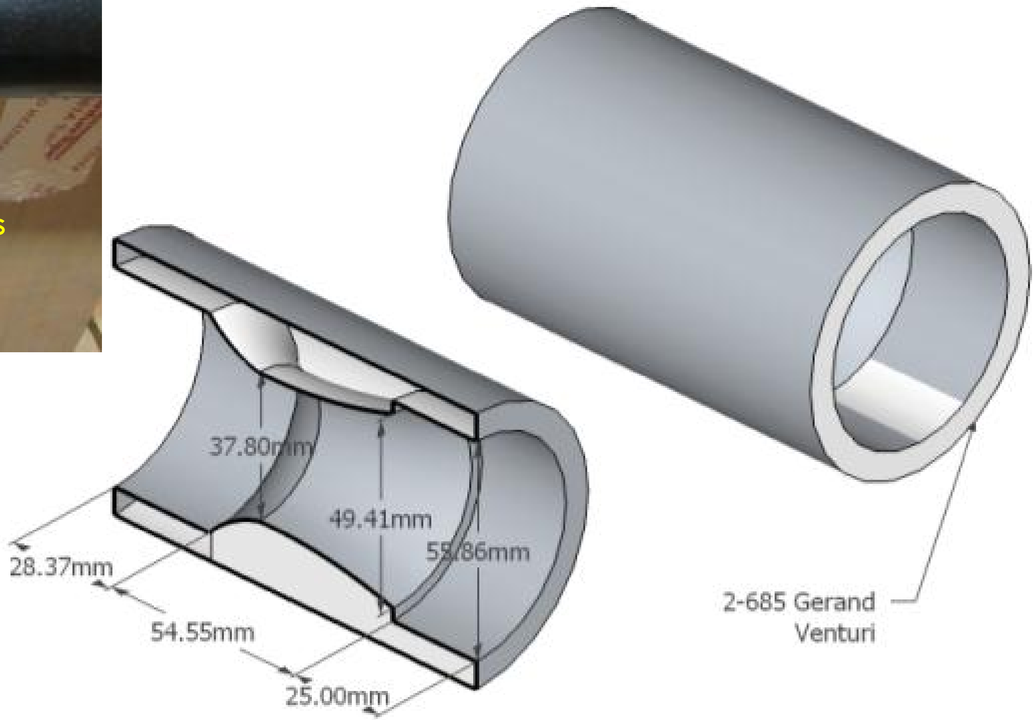
in-line reference airflow meters

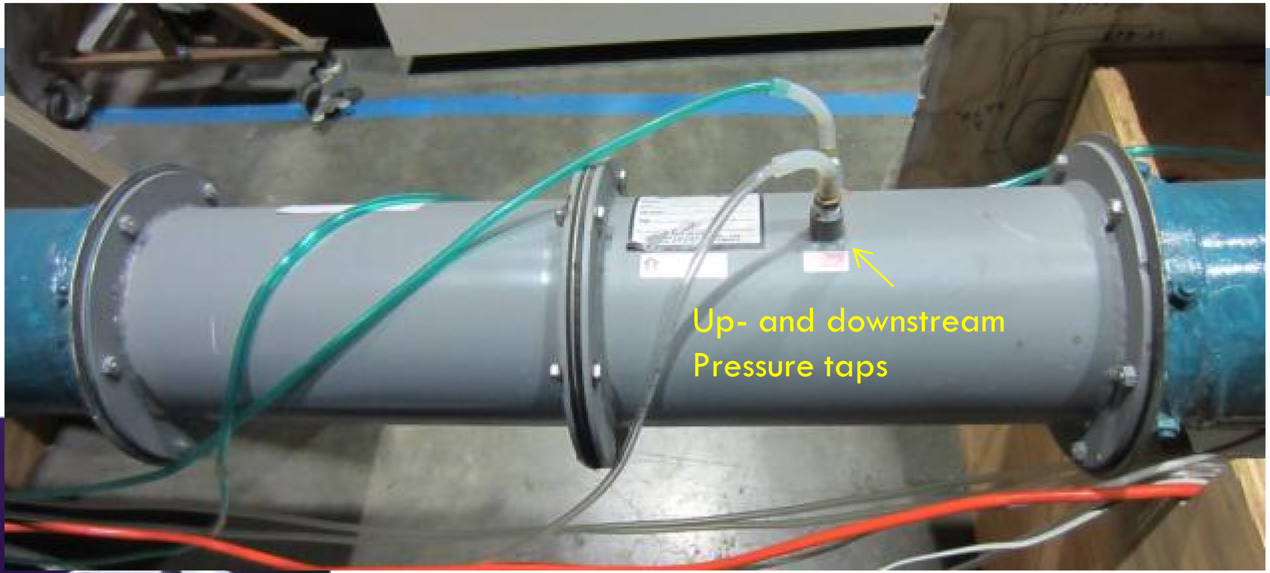
2 – 685 Gerand Venturi flow meter

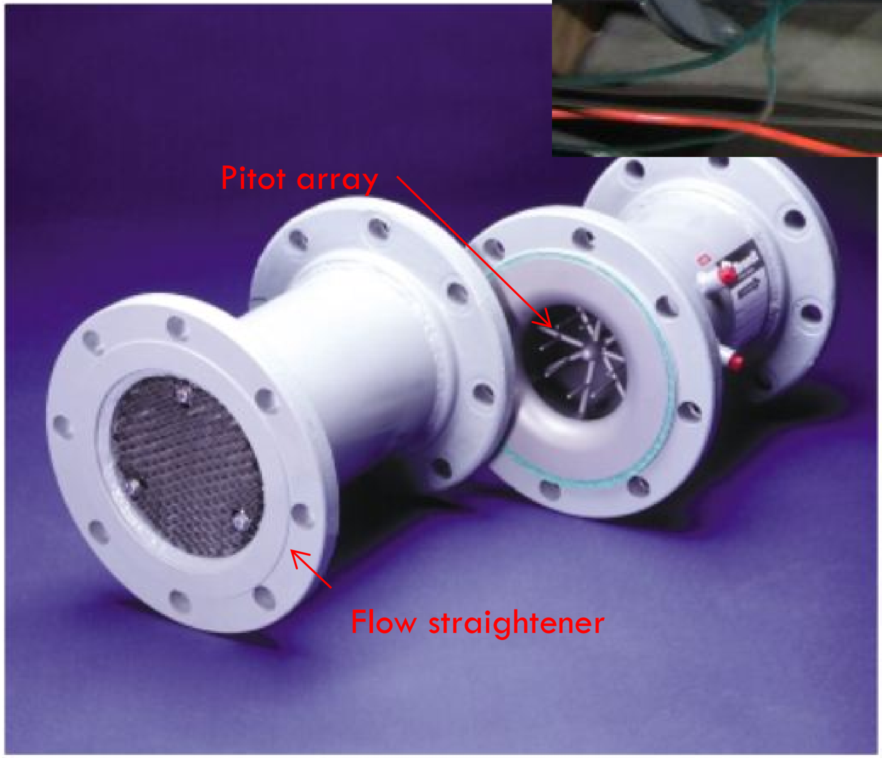
- Used to measure low flows (15 – 60 cfm)





Thermo Brandt 6” NZP 1000 Series Flow Sensor
- used to measure high flows (60 – 225 cfm)





Low flow reference meter calibrated using tracer gas


testo 417
6-4


6-4