Airtightness Testing of Multi-Unit Residential Buildings

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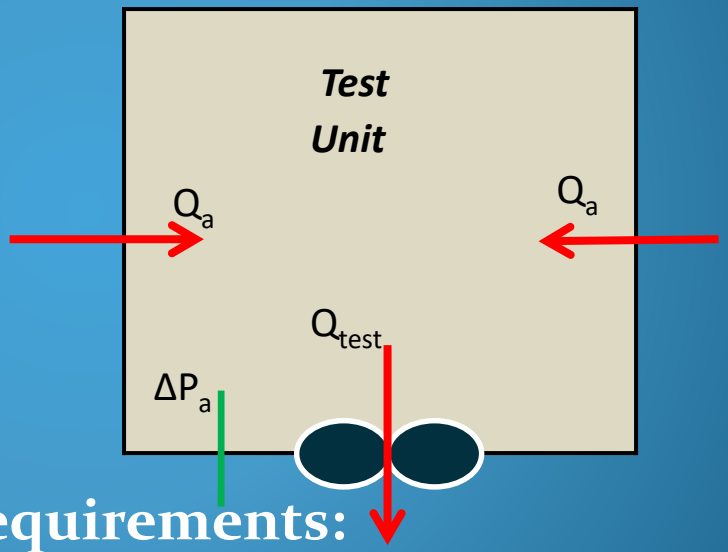
Project Objective:

Develop an improved method of performing airtightness tests on MURB's, which accounts for both envelope and partition leakage.

Testing Detached Houses

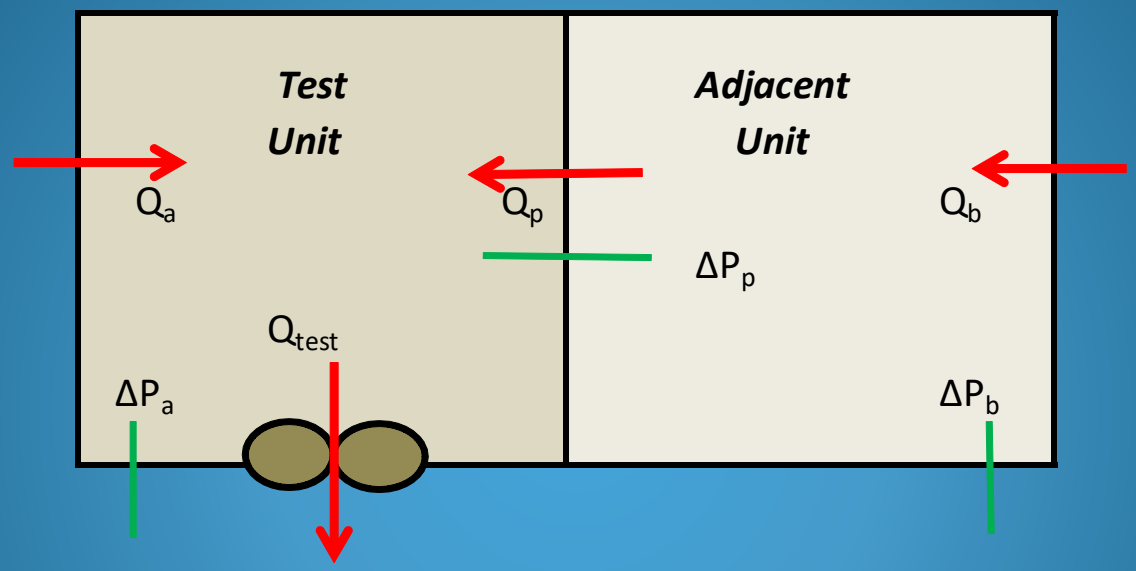
- Basic protocol has been in place for 30 years (CGSB 149.10) and hundreds of thousands of tests have been successfully performed during that time.

- $Q = C\,\Delta P^{n}$
  where:
  C = Flow Coefficient
  n = Flow Exponent



- Equipment & resource requirements:
  - 1 blower door
  - 1 micromanometer (2-channel)
  - 1 operator
  - 1 to 2 hours on-site

What About MURB's?



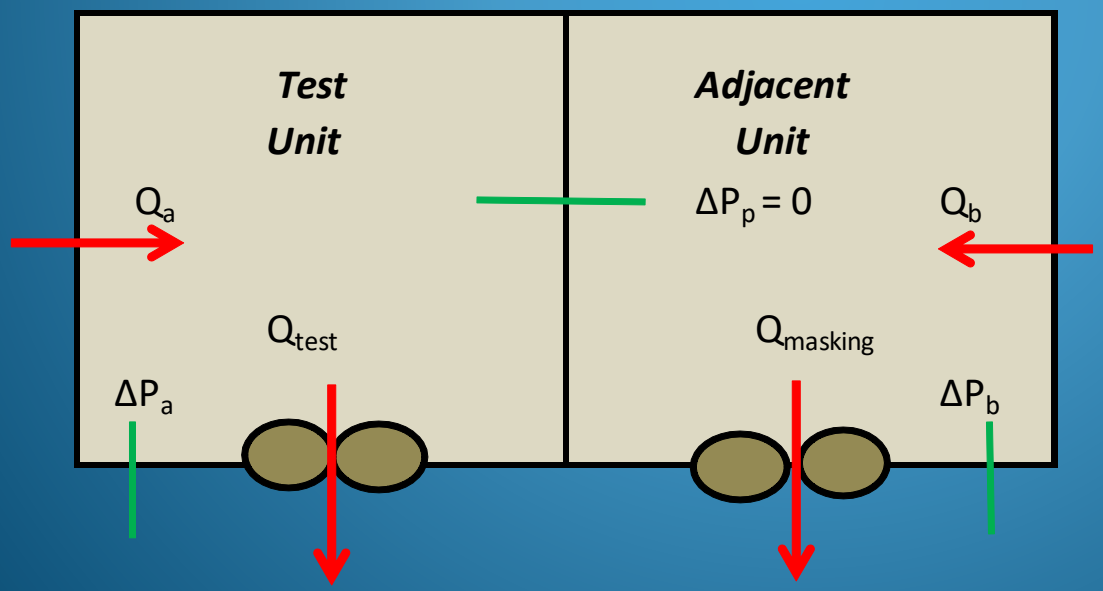
MURB's are a problem because Q_{test} includes both the stuff we want (envelope leakage of the Test Unit) and stuff we often don't want (partition leakage Q_p).

Common practice has been to treat partition leakage (Q_p) as part of the overall suite leakage.

But, What If You Want To Measure the Partition Leakage?

Various Options Exist:

1. Simultaneous Depressurization



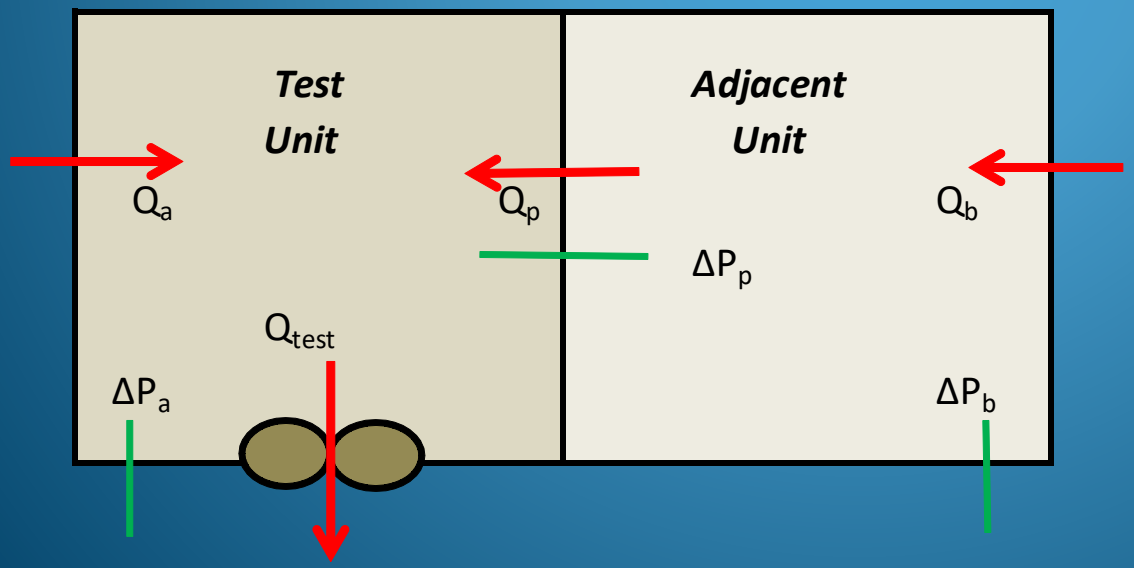
Disadvantages:

- Requires two blower doors & two operators.
- Very sensitive to measurement error as the partition becomes tighter.

But, What If You Want To Measure the Partition Leakage?

Various Options Exist:
2. Concordia Technique

Disadvantages:
- Assumes:
  $n_p = 0.65$
  $n_a = 0.65$
  $n_b = 0.65$



If All Units Access A Common Area, Then A Whole Building Test Can Be Performed*

*If you have the equipment and the bodies and the time (although access to each unit may not be necessary)

Testing MURB's

All existing techniques suffer from one (or more) of the following problems:

- **Need for multiple blower doors**
- **Need for multiple operators**
- **Need to make assumptions about the flow characteristics of the building (e.g. n = 0.65).**

Basically, our objective was to develop a new technique which did not suffer from these limitations.

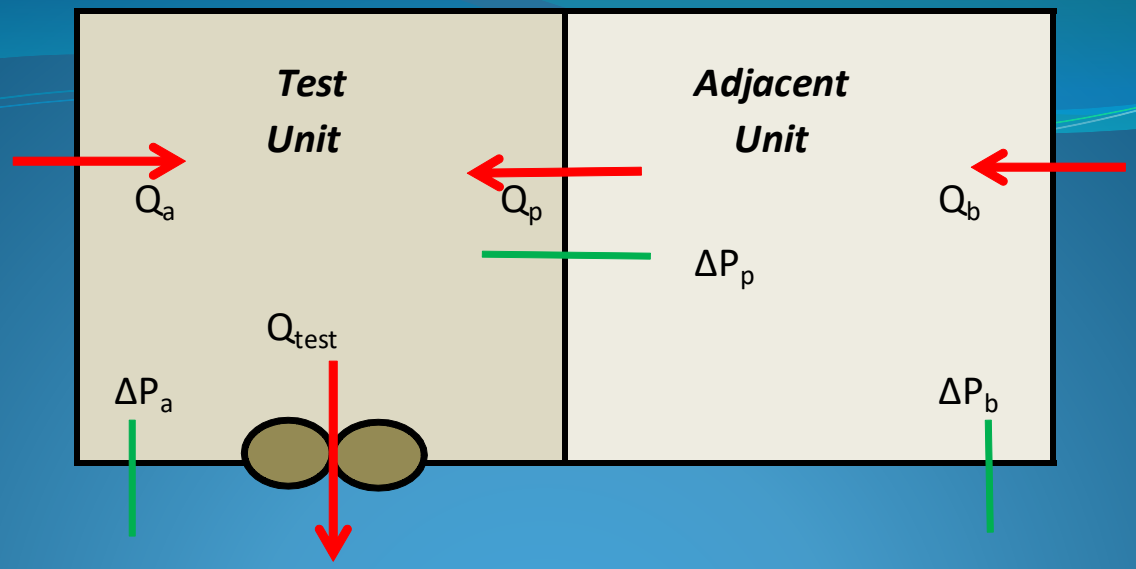
What Is The Genesis Of The New Technique?

Initially, a variation of the "Open a door/close a door" technique was developed. **It worked superbly in a trial test!**

And then failed miserably on actual MURB's.

This led to a detailed examination of the basic fluid mechanics involved in MURB airtightness tests which led – eventually – to this equation…

$$C_b/C_p = \Delta P_p^{np} / (\Delta P_a - \Delta P_p)^{nb}$$



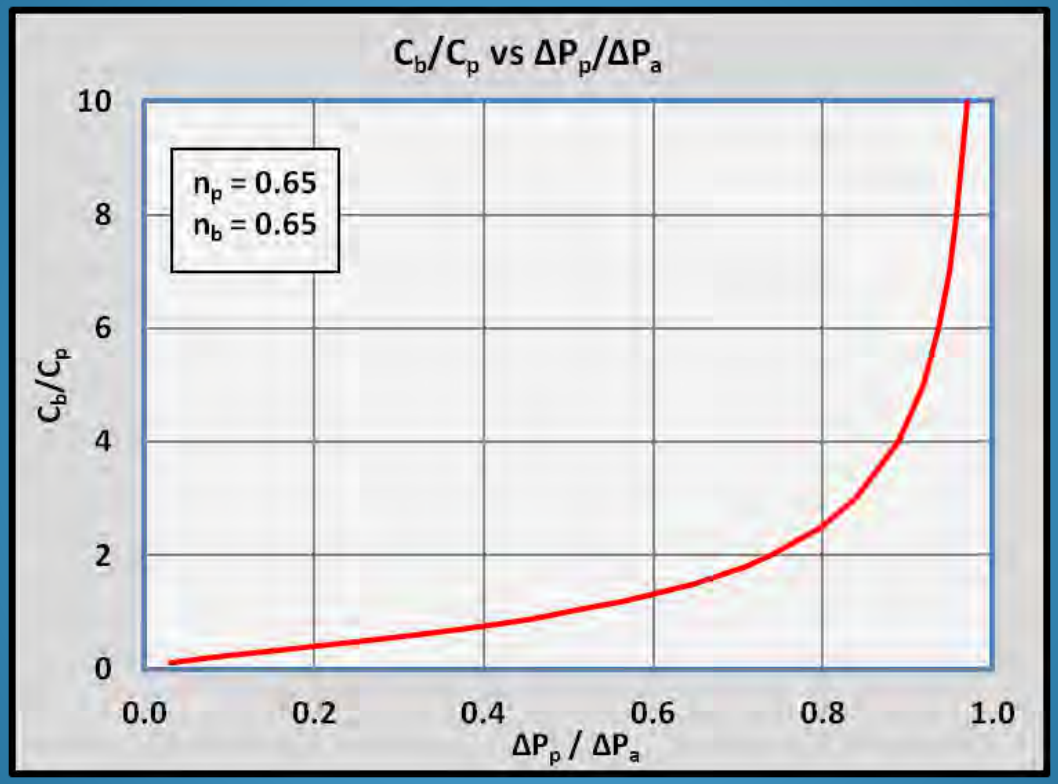
$$C_b/C_p = \Delta P_p^{np} / (\Delta P_a - \Delta P_p)^{nb}$$

Fundamentally, this tells us that the ratio of the Flow Coefficients (of the Adjacent Unit and the partition) can be determined by measuring the pressure differentials across the Test Unit (Δp_a) and the partition (ΔP_p) provided we know – or can estimate – the Flow Exponents.

If we conduct A/T tests on both units, then we know n_b.

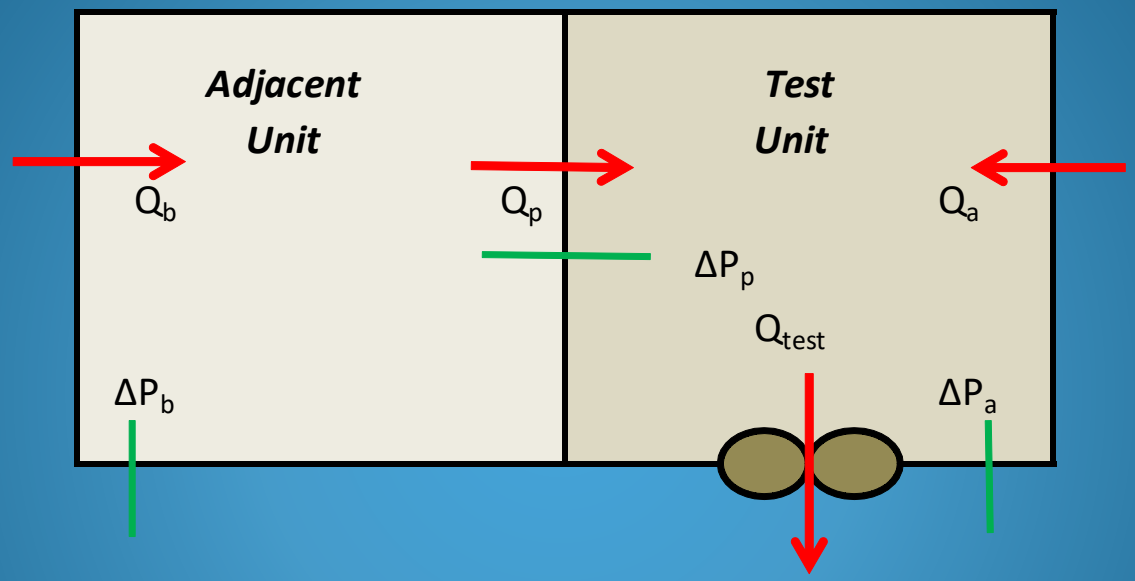
So, if we know **C_b/C_p, and** can measure C_b and n_b --- this means we can Determine C_p!

This Also Explains Why Tight Partitions Are So Difficult To Measure



Fundamentally, this shows that with a Pressure Ratio approaching 1.0, the error in the C_b/C_p ratio increases significantly and the accuracy of any test method, which relies on these two pressure measurements (ΔP_p and ΔP_p), will degrade.

How Does The New Technique Work?

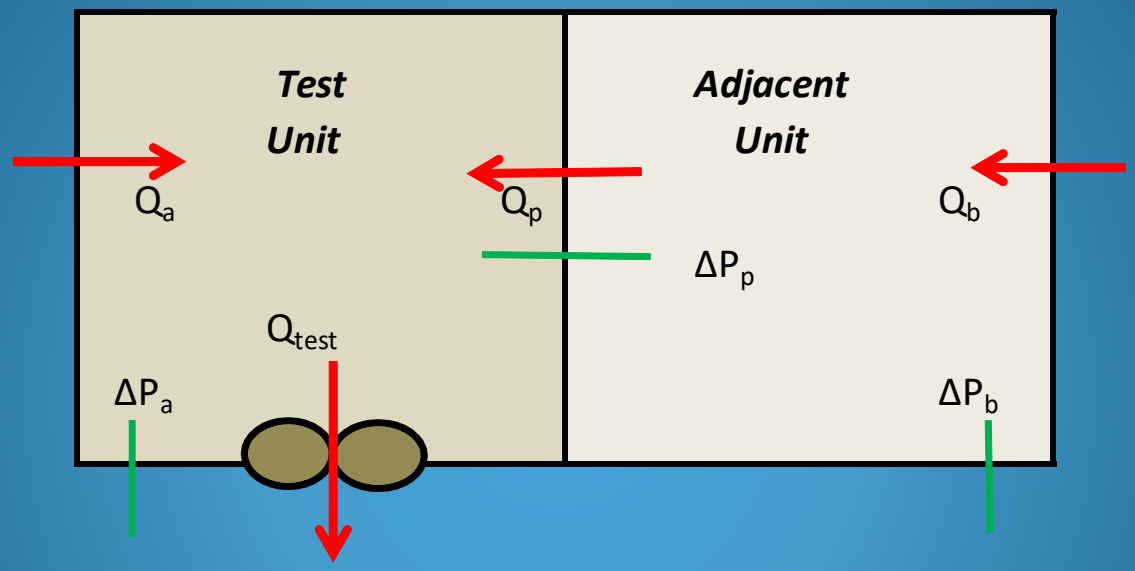


In its simplest form: To measure the flow characteristics of the partition between a Test Unit and its Adjacent Unit…

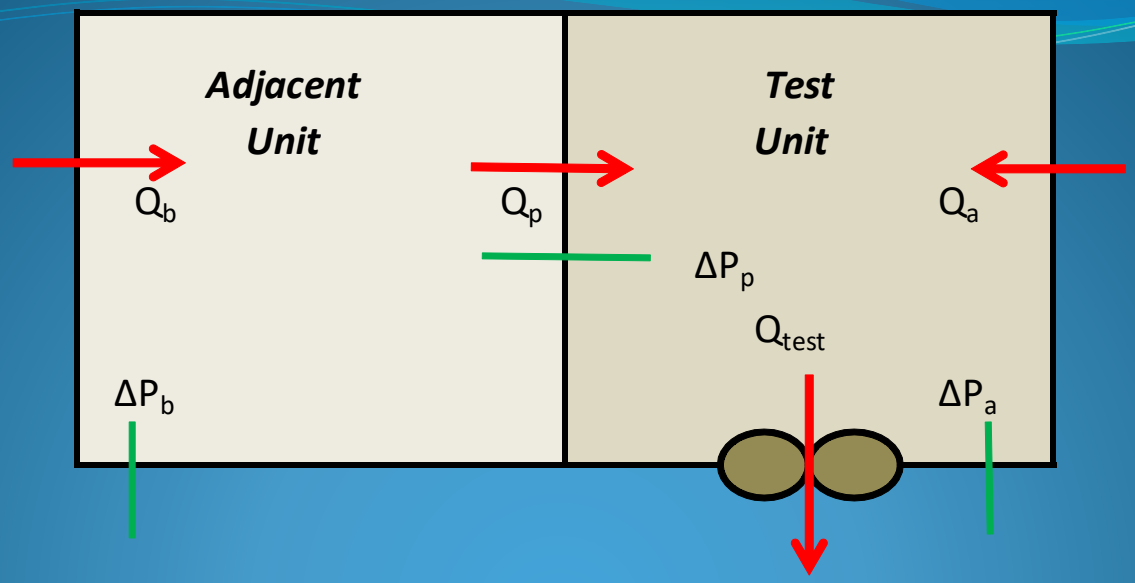
- **A/T the Test Unit, c/w partition ΔP_p**
- **Repeat with second unit defined as the Test Unit**

So, How Does The New Technique Work?

In Slightly More Detail



Step 1 – Set up B/D in the Test Unit
Step 2 – Add a pressure line between the Test Unit and the Adjacent Unit
Step 3 – Perform CGSB 149.10 test on Test Unit and
Step 4 – Measure ΔP_p & ΔP_a when $\Delta P_a \approx 100$ to 125 Pa.



Step 5 – Move B/D to second suite (the new "Test Unit")
Step 6 - Perform CGSB test on (new) Test Unit
Step 7 – Measure ΔP_p & ΔP_a when $\Delta P_a \approx 100$ to 125 Pa
Step 8 - Analyze A/T results using mfgr's software
Step 9 - Perform final analysis using spreadsheet, with inputs for C, n and ΔP_p from each test. The result is C_p and n_p.
Step 10 – The partition leakage can then be subtracted from the envelope leakage.

The Analysis

When the two sets of airtightness results (C's & n's), along with the corresponding values for ΔP_p and ΔP_a are input into the spreadsheet, it calculates the partition's Flow Coefficient (C_p) using the following formula:

$$C_p = \frac{C_{test} / [\Delta p_p / (\Delta p_a - \Delta p_p)]^{nb}}{\{1 + 1 / [\Delta p_p / (\Delta p_a - \Delta p_p)]^{nb}\}}$$

Assumptions (there always has to be some):

1. The partition Flow Exponent is equal to the envelope Flow Exponent (measured in the A/T test), i.e. $n_p = n_b$.
2. No by-pass flow.

So, does it work?

Example #1

Analysis Spreadsheet

Method 2 Calculator

Pressure Ratio Measured at ≈ 90Pa

Address:	**St. Annes Road**				
Date:	26 Jan./16				
Test Unit ("a"):	#15		**Test Unit ("a"):**	#16	
Adjacent Unit ("b"):	#16		**Adjacent Unit ("b'**	#15	
A/T test results:			**A/T test results:**		
$C_a + C_p$ =	85.8	cfm/Pa^n	$C_b + C_p$ =	82.1	cfm/Pa^n
n_a =	0.632		n_b =	0.607	
ΔP_a =	88.3	Pa	ΔP_a =	90.2	Pa
ΔP_p =	85.45	Pa	ΔP_p =	87.75	Pa
Partition Leakage Cha			***Partition Leakage Characteristics:***		
Test Unit:	#15		**Test Unit:**	#16	
C_p =	9.2	cfm/Pa^n	C_p =	8.1	cfm/Pa^n
n_p =	0.607		n_p =	0.632	
Q_{10} =	37	cfm	Q_{10} =	35	cfm
Q_{50} =	99	cfm	Q_{50} =	96	cfm
Average Values			**Percent Variation:**		
C_p =	8.7		C_p =	14%	
n_p =	0.620		n_p =	-4%	
Q_{10} =	36		Q_{10} =	8%	
Q_{50} =	98		Q_{50} =	4%	
C_b/C_p =	7.9		C_b/C_p =	9.6	

Example #2

Analysis Spreadsheet

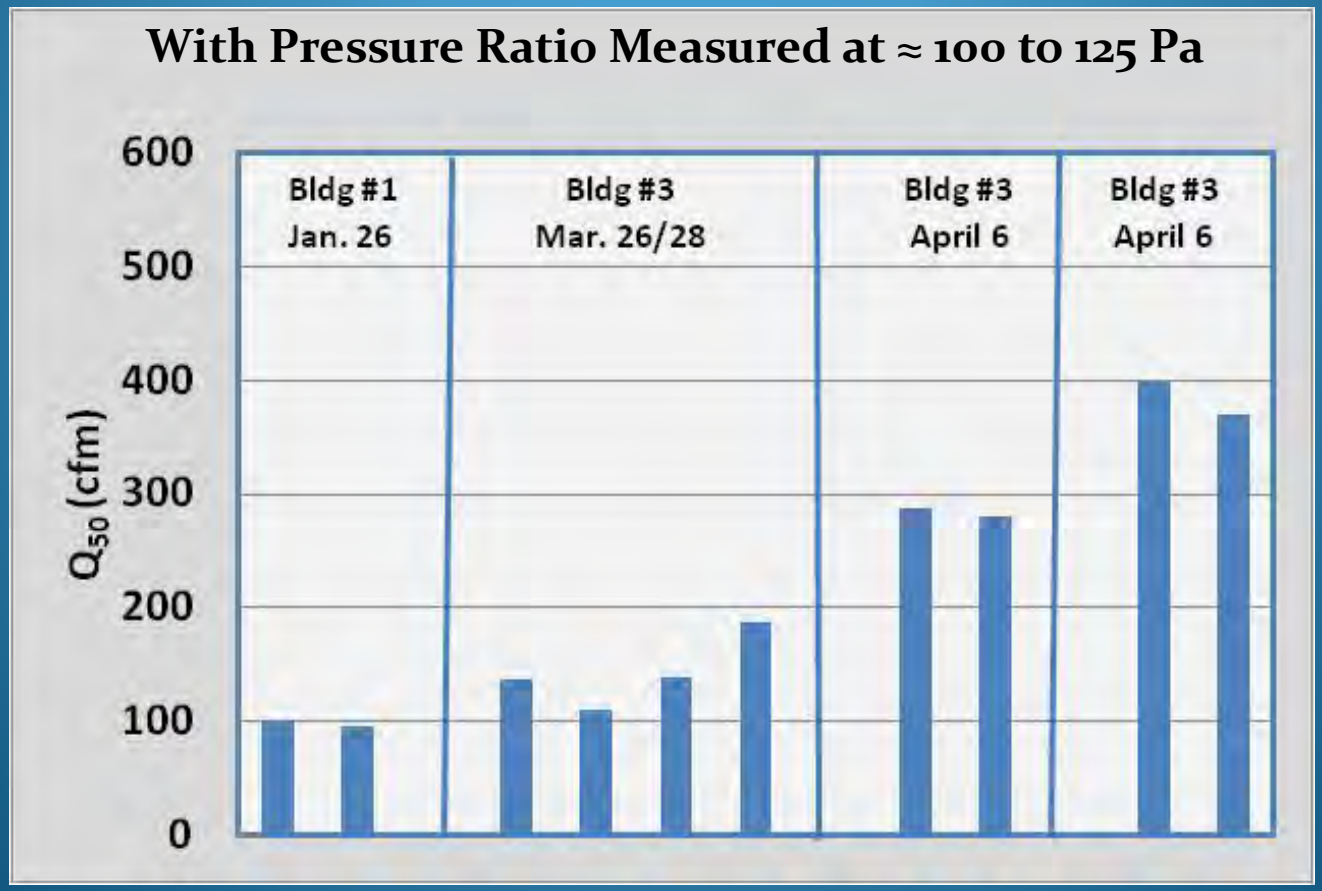
Method 2 Calculator

Pressure Ratio Measured at ≈ 100Pa

Address:	**Cavalier Road**				
Date:	6 April/16				
Test Nos.	#5 & #11		**Test Nos.**	#11 & #5	
Test Unit ("a"):	#24	Open By-Pass	**Test Unit ("a"):**	#23	Open By-Pass
Adjacent Unit ("b"):	#23		**Adjacent Unit ("b'**	#24	
A/T test results:			**A/T test results:**		
$C_a + C_p =$	100.7	cfm/Pa^n	$C_b + C_p =$	104.2	cfm/Pa^n
$n_a =$	0.644		$n_b =$	0.619	
$\Delta P_a =$	101	Pa	$\Delta P_a =$	101	Pa
$\Delta P_p =$	75.4	Pa	$\Delta P_p =$	80.3	Pa
Partition Leakage Cha			***Partition Leakage Characteristics:***		
Test Unit:	#24		**Test Unit:**	#23	
$C_p =$	35.3	cfm/Pa^n	$C_p =$	29.7	cfm/Pa^n
$n_p =$	0.619		$n_p =$	0.644	
$Q_{10} =$	147	cfm	$Q_{10} =$	131	cfm
$Q_{50} =$	398	cfm	$Q_{50} =$	368	cfm
Average Values			**Percent Variation:**		
$C_p =$	32.5		$C_p =$	19%	
$n_p =$	0.632		$n_p =$	-4%	
$Q_{10} =$	139		$Q_{10} =$	12%	
$Q_{50} =$	383		$Q_{50} =$	8%	
$C_b/C_p =$	1.95		$C_b/C_p =$	2.39	

Field Trials – All Results

Results within blue borders are tests of the same partition wall and can be compared to each other.



Further Thoughts

Although it has only been tested on vertical partitions (walls), the technique should also work on horizontal partitions (floors/ceilings) and attached garages. The fluid mechanics are all the same.

The technique has a built-in check function since the two A/T tests are measuring the leakage characteristics of the same partition surface (although in different directions) and should therefore give similar results (±10% ?).

Some Recommendations For Further Work On The Technique

1. Explore improvements to allow an explicit solution to the partition flow exponent (n_p).
2. Explore the issue of by-pass leakage in more detail.
3. Further explore the protocol for measuring the partition pressure differentials.
4. Explore by-pass flow in more detail.
5. **Evaluation by others!**

Summary

A new technique has been developed for measuring the airtightness of MURB's which permits both the envelope and partition leakage to be measured.

Compared to a standard CGSB 149.10 test, the new technique requires only one additional measurement (ΔP_p).

Equipment & resource requirements:

- 1 blower door
- 2 micromanometers (2-channel), preferably one with a "Pressure Hold" capability
- 1 operator
- 1 to 2 hours on-site (per unit)