Introduction to Airtightness

Paul Jennings, Air Leakage Specialist, Aldas

October 1st 2020

Logistics:

- **Webinar recording on AECB website**
- **Presentation notes also on AEC website**
- **The only stupid question …**

  is one you still have in your head after the session is over!
- **If further questions or outstanding items e-mail:** doorfanman@hotmail.com

Paul Jennings:

- Testing since 1987 – courtesy of Ken Livingston & the GLC!
- Tested, surveyed, advised on 1000's buildings in the UK & overseas
- From the first Passivhaus & EnerPHit projects:

Y Gaol, Machynlleth

DVFP Offices, Machynlleth

Grove Cottage, Hereford

Airtightness

- A big subject!
- This is just an introduction
- To tailor presentation, a couple of questions:

- What is your profession/ involvement?
- Are you primarily working in newbuild or refurbishment?

10-year retests

Retested on October 18th 2018:

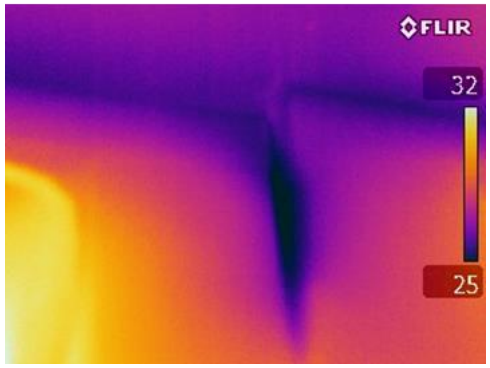
Y Foel, detached house

0.4 AC/hr @ 50 Pa

Hyddgen School

1.6 AC/hr @ 50 Pa

Y Foel leaks



- Leakage at top of window to door joint

- Leakage around poorly sealed solar thermal penetration

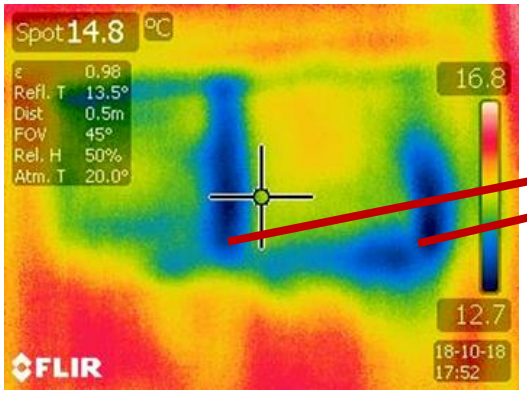
Machynlleth Hyddgen School: + 10 years

- Originally tested 29th August 2008
- Formerly was Dyfi Valley Forward Partnership Office
- Retested on October 18th 2018
- 2008: 0.3 AC/hr @ 50 Pa
- 2018: Increased to 1.6 AC/hr @ 50 Pa

Hyddgen School

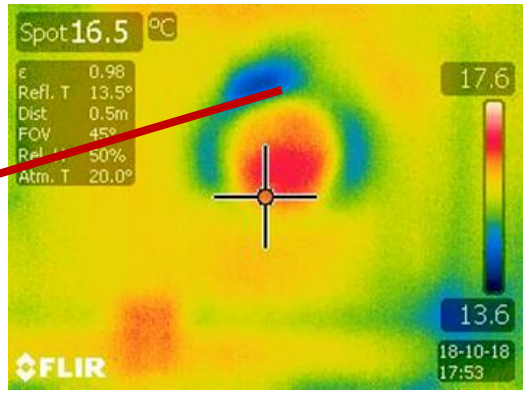
IT Defects

- Hyddgen use changed from public sector office to school
- Major IT change, extra cooling load – leaky services



Leakage around extract fans through de-glazed window

Server Room

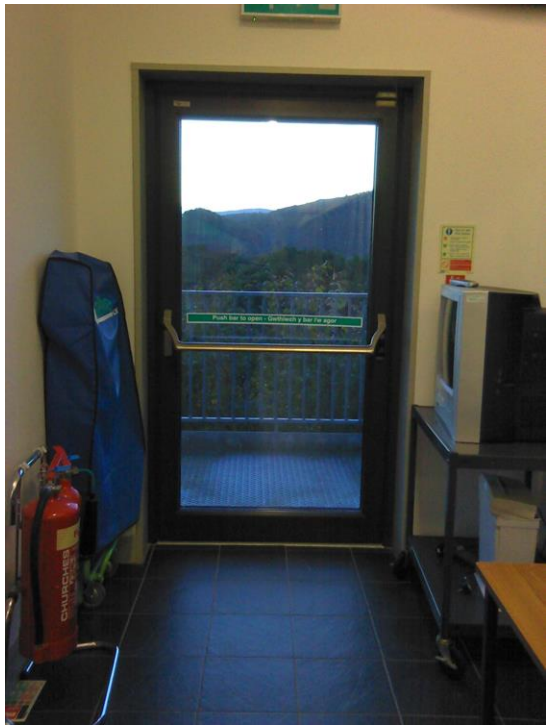


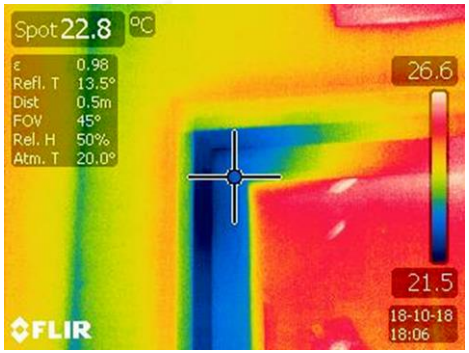
Leakage around poorly sealed future services duct

Hyddgen School Fire Escape Doorway

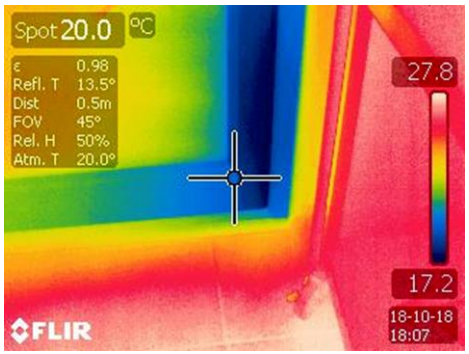
Upper Fire Escape Door, at end of access corridor to upper classrooms

Clearly door no longer seals – but is it due to warping of the timber frame or possibly subsidence of the building?





Major leak on top left corner



Also bottom right corner

Getting to now:

EnerPHit success: Erneley Close, Manchester

- 2 blocks, 32 maisonettes
- New roofs, windows & doors
- Full external insulation
- Team of 4 airtightness champions
- Completed in May 2015
- Excellent resident feedback & post occupancy evaluation

Lessons from Erneley Close:

Lessons during construction:

- Detailed survey required
- Be flexible
- Develop a solution on sample dwellings, then apply generally
- Train & develop airtightness champions
- Avoid works chasing funding
- Avoid leaving problem areas until the end

Context:

- **Where does the airtightness fit into the successful delivery of a low-energy newbuild or refurbishment?**
- **Essential! – one of several steps that are needed to guarantee success**
- **A substantial foundation for successful project delivery**
- **Airtightness provides an absolute measure of quality**

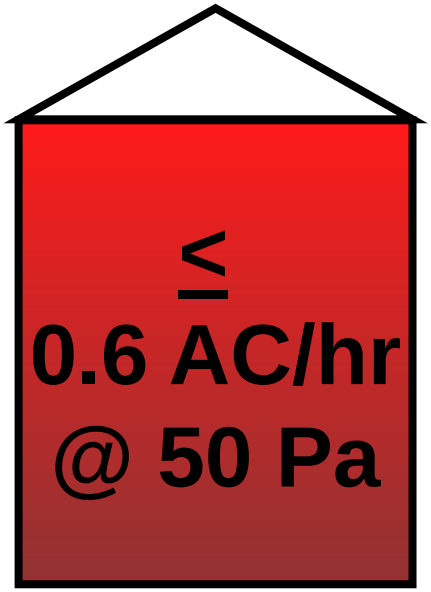
Fundamental of Airtightness

Expressed in two ways:

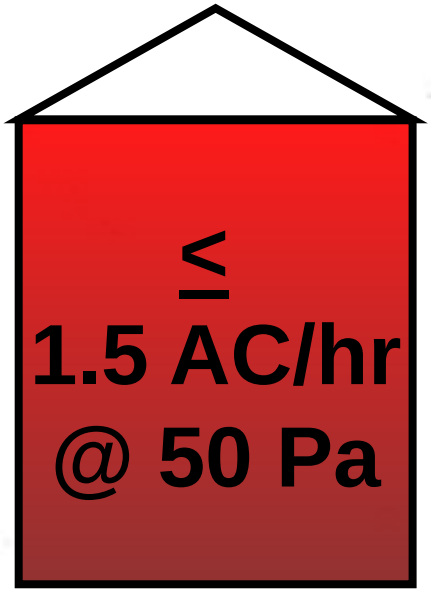
- **Air Permeability, units $m^3/hr/m^2$ of total surface area, used in Building Regulations**
- **Air Changes, units AC/hr – volumetric**
- **Both quoted at 50 Pa imposed pressure differential ≈ 5mm of H_20 / 20 mph wind**
- **For Zero Carbon and/or sustainability, a good or excellent level of airtightness is required**

Good Airtightness?

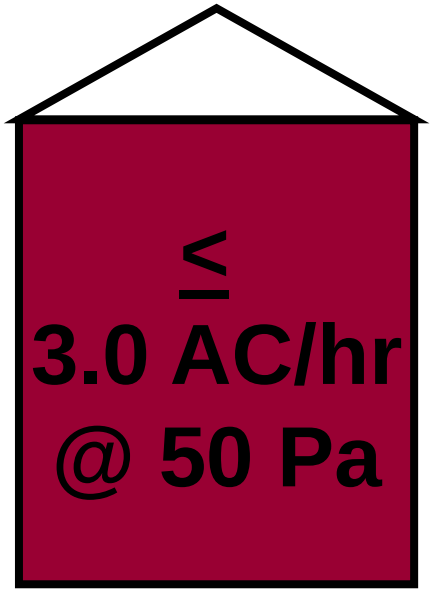
Somewhere between:



PassivHaus newbuild standard



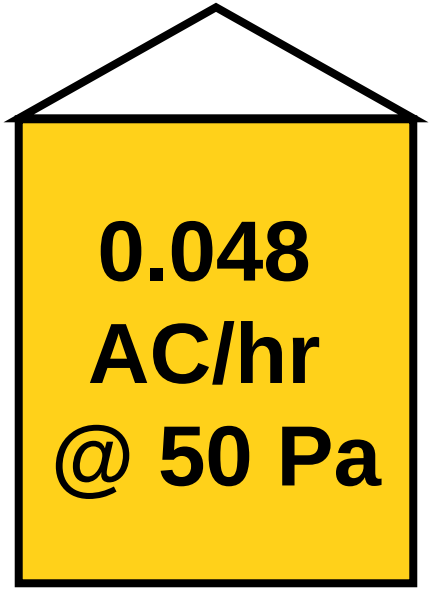
Super-E Standard – (Canada)



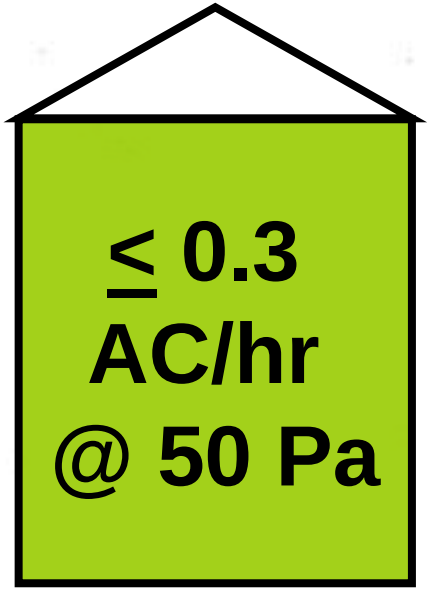
AECB Building Standard

Excellent Airtightness?

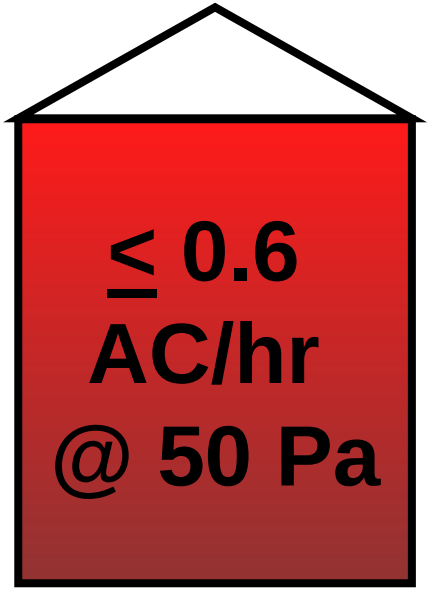
Somewhere between:



Best Achieved – personally, & in UK to date



Passivhaus good practice



PassivHaus Standard - newbuild

Larch Corner Bungalow

- CLT dwelling, TFA 162.5 m^2
- Acceptance testing in March 2019
- Average AC/hr: 0.048 @ 50 Pa
- i.e. Passivhaus 0.0
- Average ELA < 2 cm^2
- Most airtight UK dwelling

Alongside Airtightness:

- Effective ventilation – to get rid of moisture and maintain a healthy indoor environment. Will also protect the fabric
- Limit the pollution load – e.g. avoiding building products that give off VOCs
- Extends to the contents we put into our buildings – i.e. Danish research showing harmful off-gassing from new computers
- Monitoring, especially in older buildings

Ventilate Right

1.5 ACH^{-1} @ 50 Pa, Super-E standard

3.0 ACH^{-1} @ 50 Pa, AECB Silver standard

PassivHaus

EnerPHit

Improving Airtightness

Below 1.5 AC/hr @ 50 Pa recommend MVHR

1.5 < AC/hr @ 50 Pa < 3.0 suggest MEV, or MVHR with low-carbon electricity

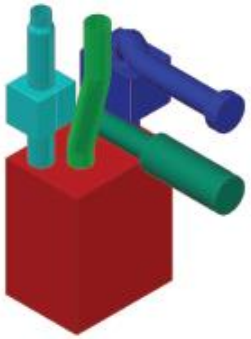
Above 3.0 AC/hr @ 50 Pa natural ventilation, or MEV for H_20 control

Ventilation Types

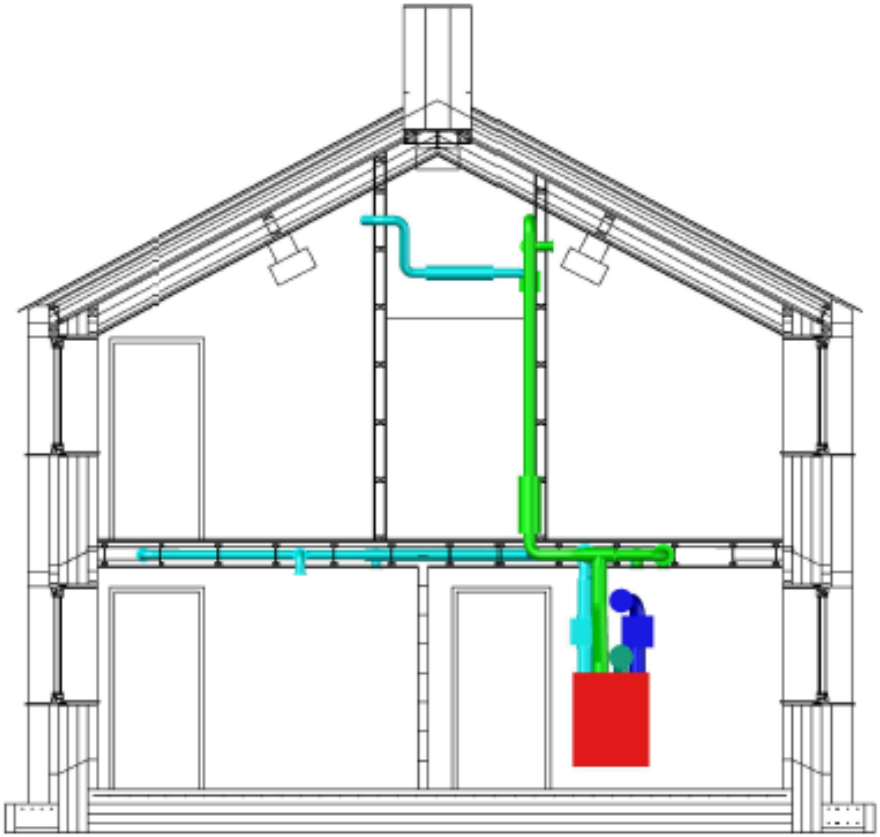
- Natural ventilation – opening windows etc.
  - NB Trickle vents are ineffective
- Mechanical extract ventilation, MEV
  - Usually in kitchens & bathrooms
  - Ideally controlled by humidity sensors, with boost option
  - Includes Demand Controlled MEV
- Mechanical ventilation & heat recovery, MVHR, with up to 95% efficiency
  - Ideally whole-house, but hard to retrofit

MVHR options

Paul (German) whole-house MVHR system



Dark blue – incoming air; at lower level, exhaust duct



Schematic section – light blue supply, green extract

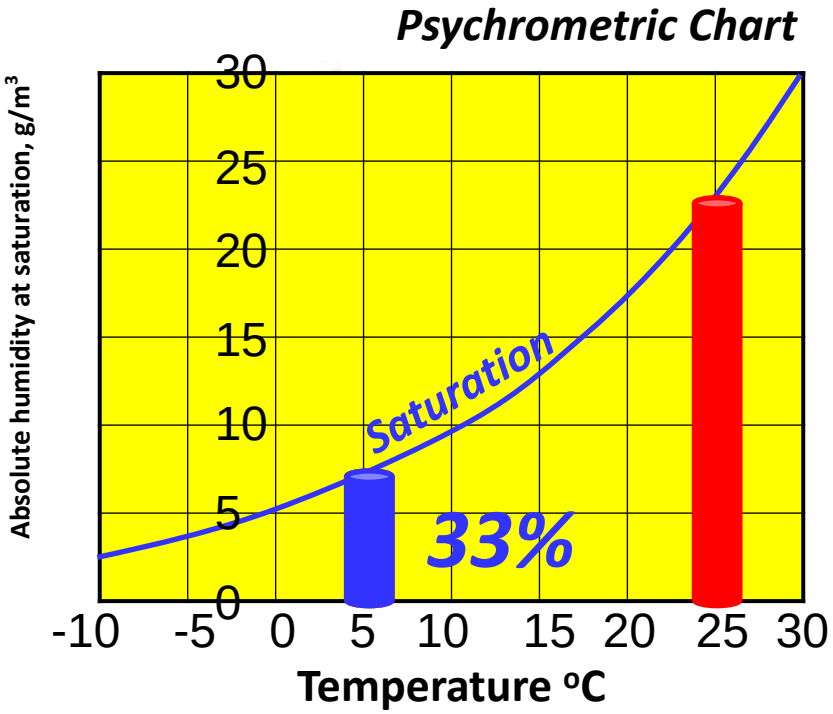
Older Buildings:

- Sustainable Traditional Buildings Alliance
- Pre-1919, solid walls
- Moisture-permeable construction
- Originally cold, hence little moisture in the air
- Now heated, much more moisture in the air
- Condensation risk

Interstitial Condensation

Humidity

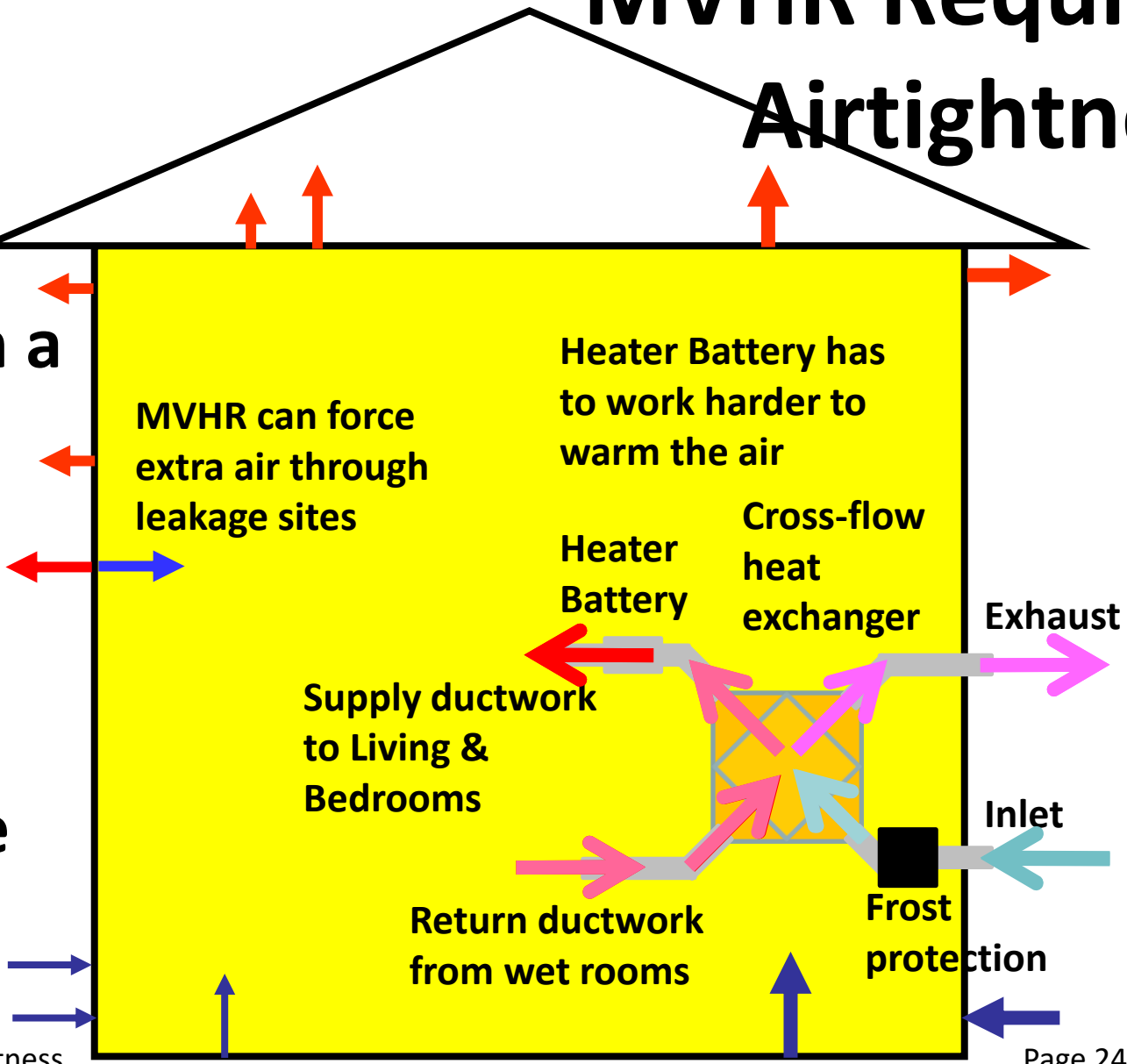
- Relative to 100%, saturation
- When droplets of H_20 condense
- Varies with ^oC
- Cold air can carry much less H_20



Hence warm moist air can deposit a lot of H_2O on meeting cold surfaces in walls or roofs

MVHR Requires Airtightness

- Works in a sealed house
- But with leaks?
- Negative effects



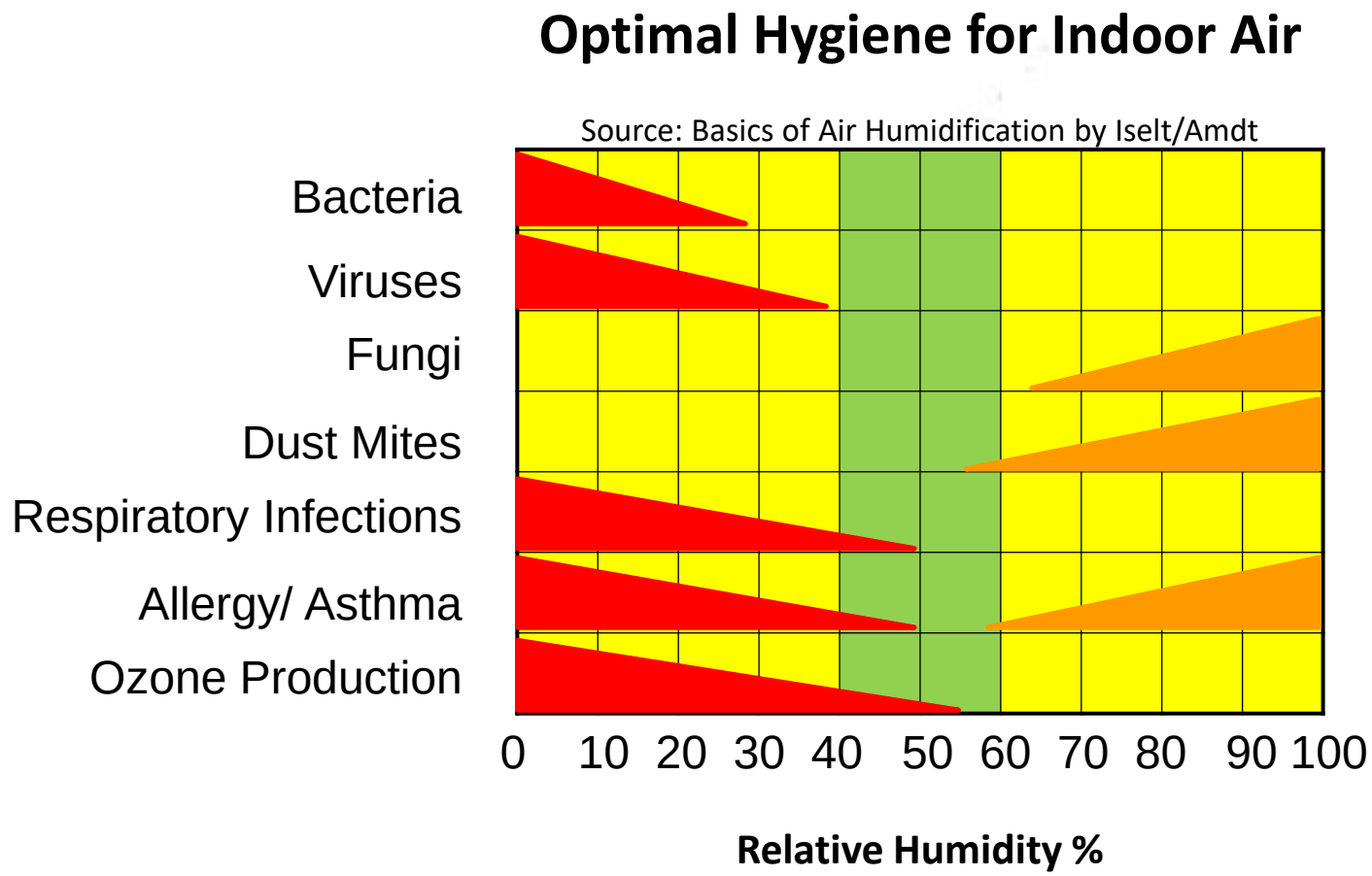
Interstitial Condensation

- Condensation on cold surfaces in walls & roof
- Gives rise to mould & rot
- Long term damage

Moisture Management

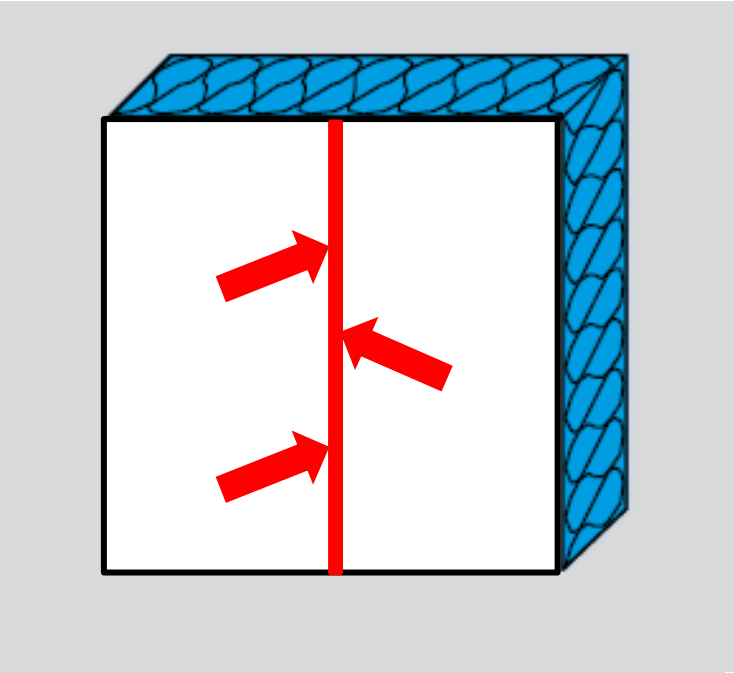
- Ensure good airtightness to limit moisture ingress into fabric
- Install MVHR, MEV or DCMEV to remove moisture at source
- Use lime, clay & similar natural materials to provide moisture buffering
- Monitor to provide long-term security

Target Humidity



Airtightness to limit moisture risk

- 1m by 1m piece of plasterboard
- If no gaps 0.5g of H_20 by diffusion in 24hr
- Add a 1mm wide gap
- i.e. 1/10th of a % by area
- Now 800g H_20 in 24hr
- Factor of 1600!



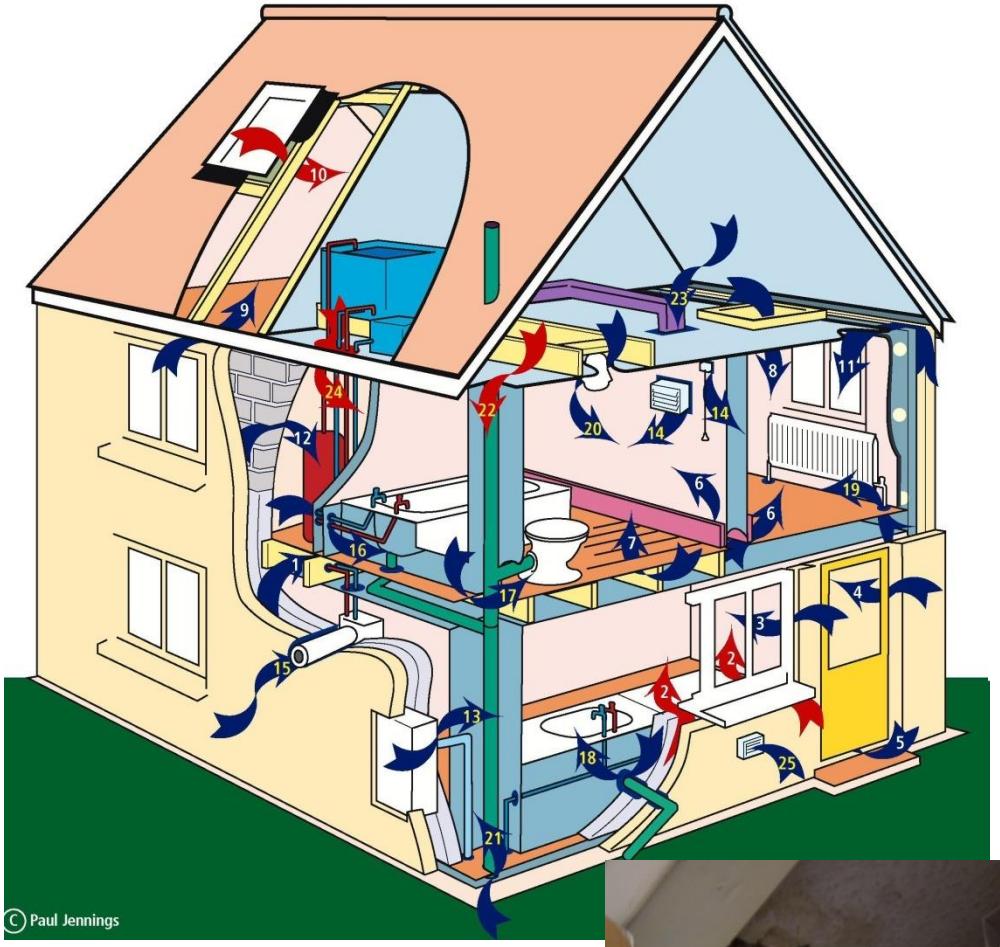
Results courtesy of Pro-Clima

Monitoring

- HygroTrac from Protimeter
- Miniature wireless sensors
- Continuously monitoring temperature & humidity
- Also dew point, moisture content, other variables
- Channelling data to a viewable web site

For more info, go to: www.gehygrotrac.com

Where buildings leak?

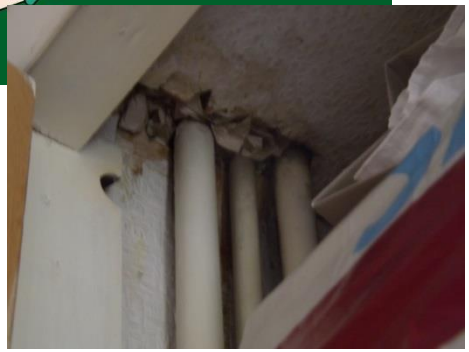


2) Under window sills

22) Hole around SVP into loft

10) Checking rooflight for leaks

24) Unsealed pipes & cables through top of airing cupboard



Refurbishment for Health:

- Design out toxins
- Upgrade & insulate fabric to:
  - Minimise cold bridges
  - Be airtight and moisture transfusive
- Include hygroscopic mass e.g. lime plaster
- Design ventilation hierarchy
  - room by room basis
  - extract pollutants at source – priority: remove moisture
- Install monitoring, with occupant feedback

Our Government's ostrich position:

- Growth in fuel poverty
- tisfaction
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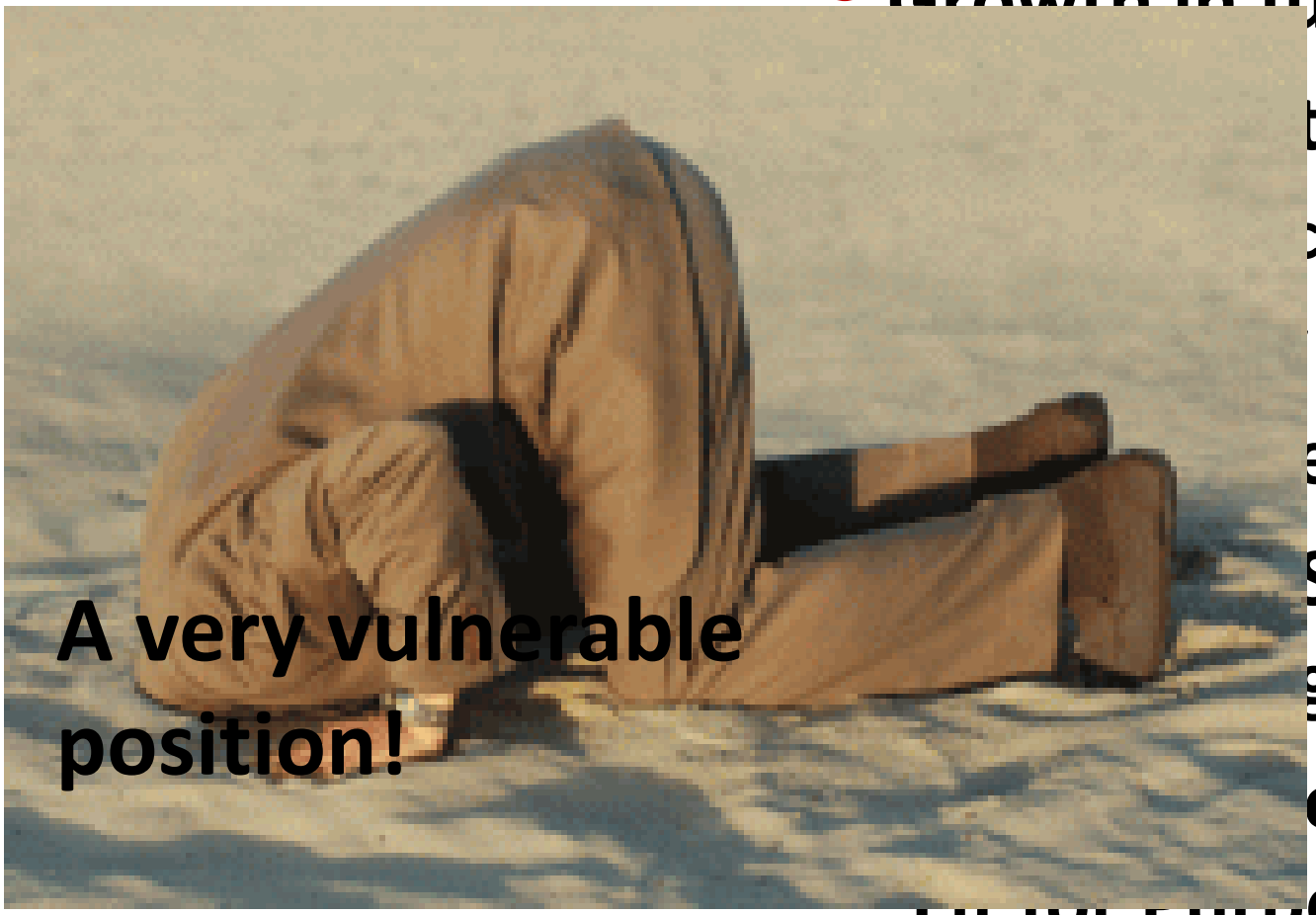


Delivering Airtightness

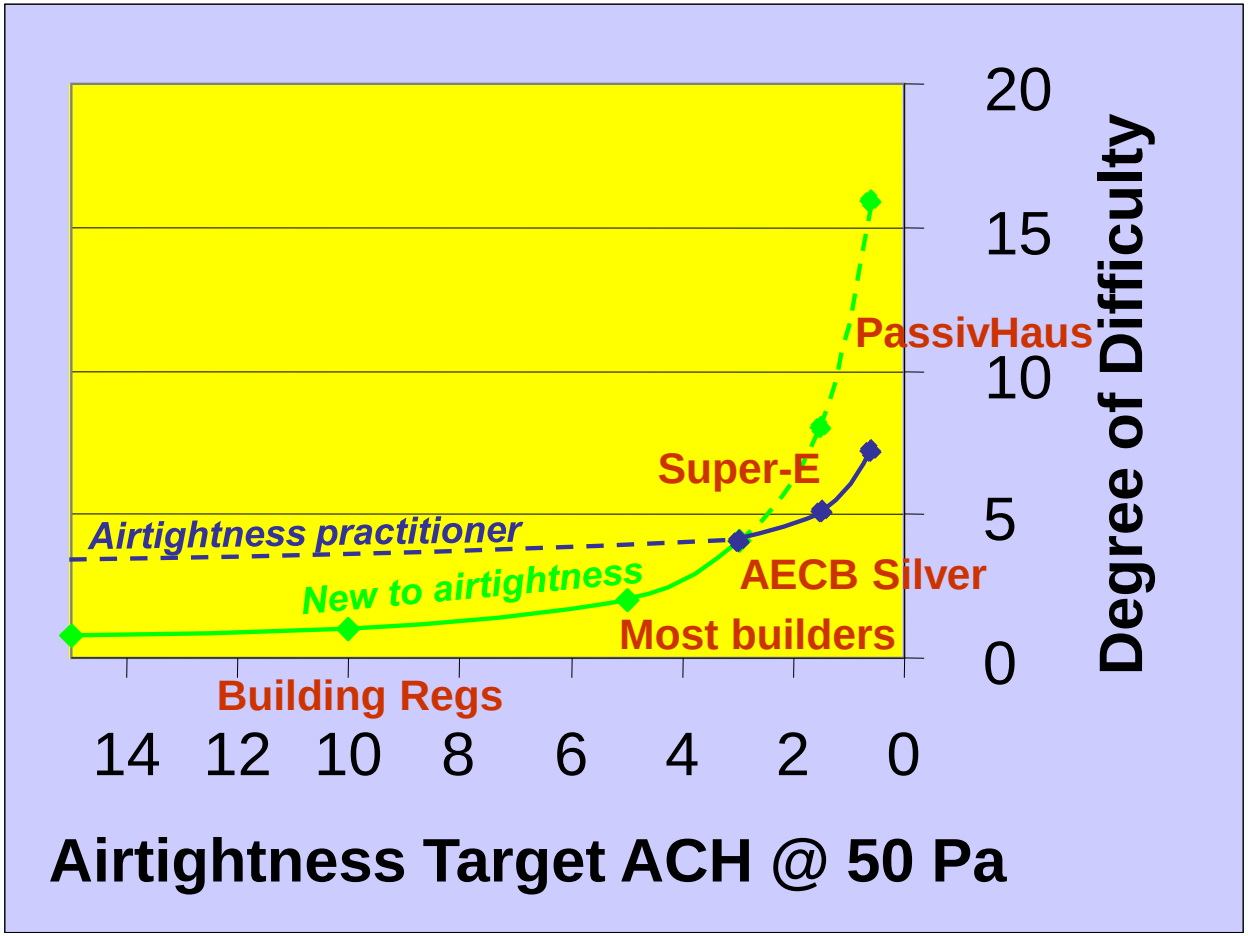
Over years of testing;

& being involved in the construction and refurbishment of both good and bad buildings;

I have concluded that:

- **Good airtightness doesn't happen by chance;**
- **Achieving a good level of airtightness is a process, and needs a plan;**
- **Know where you start – and your goal**

Achieving Airtightness



Factors affecting the delivery of good airtightness:

- **Size**
- **Complexity**
- **Voids**
- **Forethought**
- **Experience**

Delivering Airtightness

Fundamentally, about attention to detail

- **during design**
- **on site**

Introducing:

A repeatable process to deliver airtightness

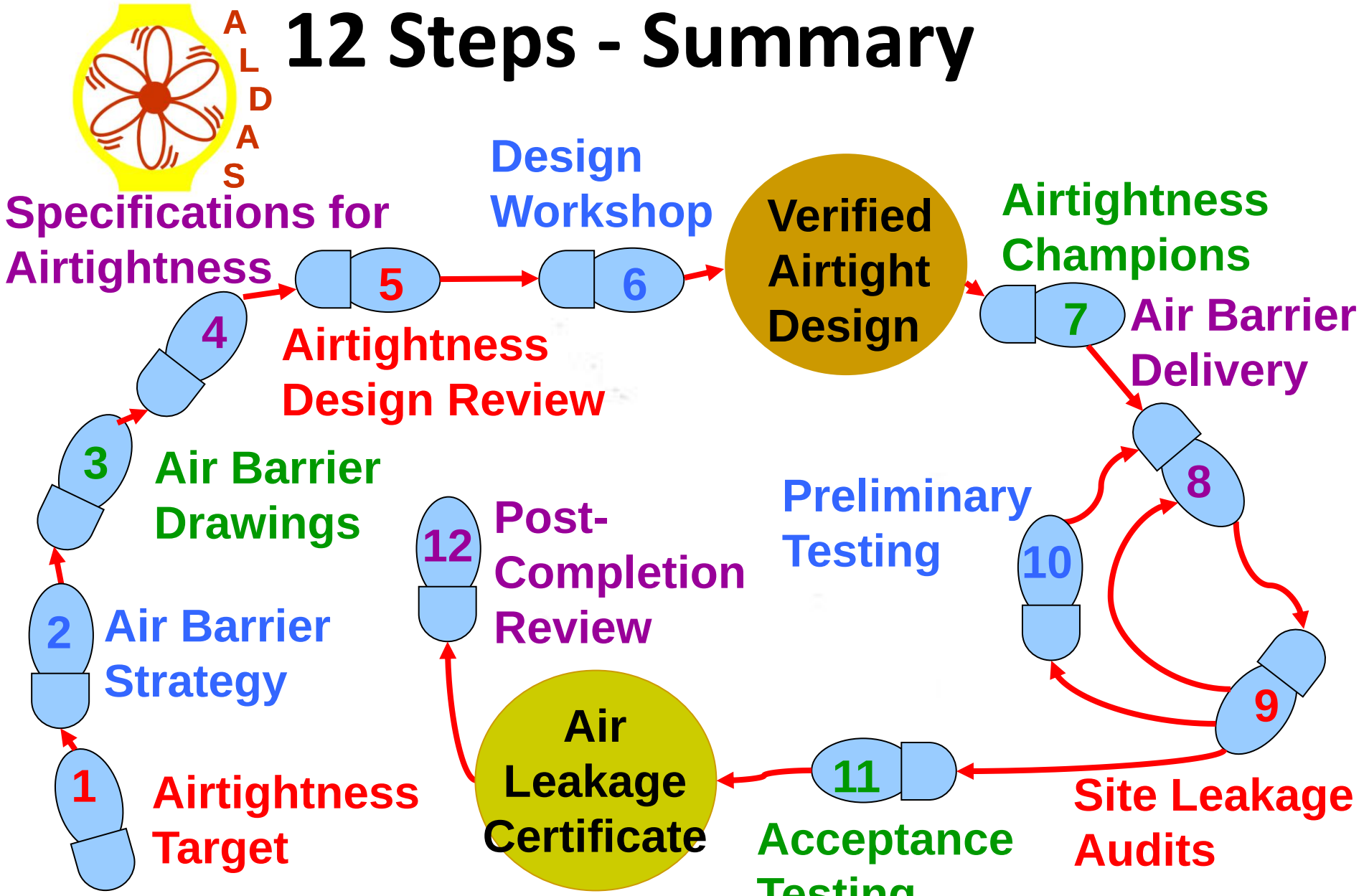
- **Verified airtight design**
- **Support systems for effective airtight construction**

12 Steps to Good Airtightness

- Developed over a decade of working on leading-edge UK low energy projects;
- Because UK construction commonly builds down to a price, not up to a standard;
- Conning and misleading the client and Building Control is normal practice
- A 12-Step program because our builders are

…… addicted to building rubbish!

12 Steps - Summary



12 Steps - Documentation

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Delivering Airtight Buildings: A 12-Step Program

To effectively and efficiently deliver buildings to high degrees of airtightness, such as the AECB Building Standard (≤1.5 AC/hr @ 50 Pa), the Canadian Super-E standard (also ≤1.5 AC/hr @ 50 Pa), and particularly the German PassivHaus standard (≤0.6 AC/hr @ 50 Pa for newbuild, ≤1.0 AC/hr @ 50 Pa for refurbishment), the UK construction industry needs to adapt and develop, otherwise contractors and others will continue to face significant difficulties, delays and additional costs.

Here we outline a 12-step program for contractors and design teams to consider for simple buildings. The diagram below summarises this approach, which is explained in more detail on the following pages:

This was originally developed more than a decade ago, in response to my continuing frustration at seeing the same mistakes and omissions giving rise to leakage issues and airtightness test values in a range of low energy buildings across the UK. There is an accompanying PowerPoint presentation, part of the training we deliver for those wishing to become Airtightness Champions. This was initially prepared in 2012, revised for a recent project in 2018.

Paul Jennings, Aldas,
May 2020

- Aldas 10-page detailed explanation of 12 Steps to Airtightness approach
- Provided as pdf on AECB website
- Contact ALDAS for further information

PassivHaus Airtightness

- Requirement: ≤ 0.6 AC/hr @ 50 Pa for newbuild
- Approximately 15x more onerous than Building Regulations
- Equivalent to a hole slightly larger than a 5p piece per 3m by 3m section of envelope
- Not achieveable with standard building materials & practices
- Note: the final test must meet this; aim for 0.3 to 0.4 AC/hr @ 50 Pa in preliminary testing

EnerPHit Airtightness

- The PassivHaus standard for refurbishment
- Requirement: ≤ 1.0 AC/hr @ 50 Pa for newbuild
- Equivalent to a hole about the size of a 10p piece per 3m by 3m section of envelope
- Often harder to achieve than the PassivHaus newbuild standard
- Note: the final test must meet this; aim for 0.7 to 0.8 AC/hr @ 50 Pa in preliminary testing

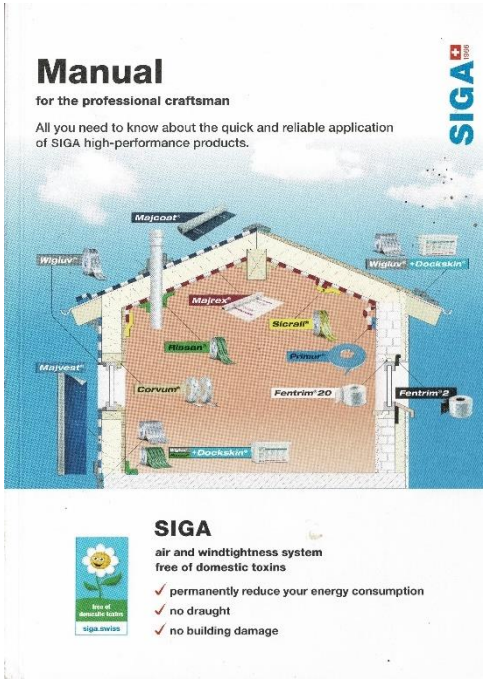
Fundamentals for airtightness

- Specify the airtightness process
- Check & recheck – design, construction positives & negatives
- Set air leakage maxima for components & building elements
- Enforce hold points

Refurbishment vs Newbuild

- Airtight refurbishment is harder than newbuild
- 4 levels of refurbishment, from an airtightness perspective:
  1) Extreme
  2) Extensive
  3) Partial
  4) Minor
- At levels 2 or 3, a pre-improvement air leakage test plus detailed leakage investigation is advisable, to:
  a) Determine starting point
  b) Identify key issues & focus design of improvements
  c) Quantify some measures e.g. impact of window replacement
- At level 1, a pre-improvement air leakage test is a minor cost and tells where you start from – but not essential

Sealing Documentation



Pro-Clima (German) sold on-line in the UK by Ecological Building Systems, Ecomerchant & others

Rothoblaas (Italian) is the third supplier of really good airtightness tapes & materials

SIGA (Swiss) sell direct through local technical advisors

For refurbishment

- Same 12-step program
- But selecting the airtightness target – more complex than newbuild
- Depends upon:
  - starting point – pre-improvement test?
  - extent of works – planning limitations?
  - MVHR included?

Penetrations

- During refurbishments, identified by early Leakage Inspection;
- Develop a schedule of penetrations and how different products are applied in each case
- Ductwork, waste pipes, water pipes, district heating, electrical cables, cable TV, telephony, broadband etc…

UK - Newbuild

- **John Williamsons Y Gaol House & DVFP New Office, both achieved Air Permeability of 0.25 in Sept. 08**

- **Lancaster Co-Housing, 47 PassivHaus**

All achieved Air Change Rate of < 0.6 ACH^{-1} in 2012/13

- **Bere Architects Ebbw Vale House**

Air Change Rate of 0.2 in May 2010

UK - Refurbishment projects

- **Andy Simmonds EnerPHit Refurb**

  Air Change Rate of 1.0, July 2010

- **Adam Dadeby's Totnes Refurb**

  Air Change Rate of 0.2, July 2011

- **Bere Architects Mayville Community Centre**

  Air Change Rate of 0.4 in June 2011

Building Regulation Targets – awaiting revision

Air Permeability Targets:	Good Practice	Best Practice
Dwellings	10.0	5.0
Mechanically ventilated dwellings	5.0	3.0

AECB Building Standard

Just a starting point!

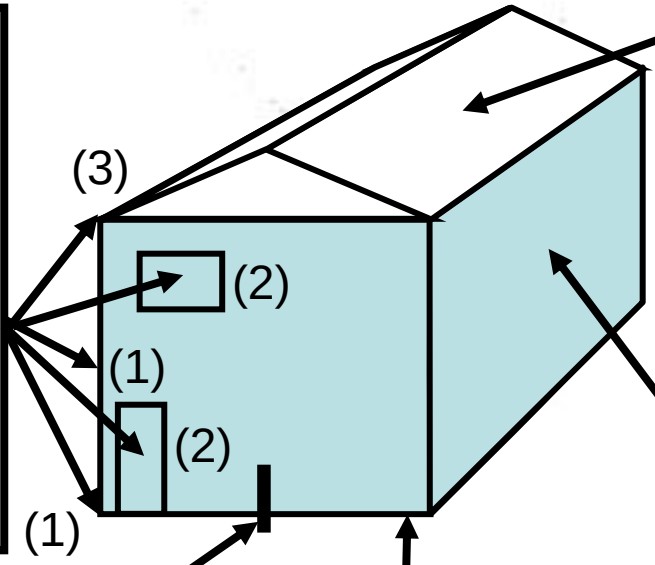
If possible aim for EnerPHit (refurbishment): ≤ 1.0 AC/hr @ 50 Pa

Or PassivHaus (newbuild): ≤ 0.6 AC/hr @ 50 Pa

Step 2: Ebbw Vale Air Barrier Strategy

- **A visual summary of the building fabric choices by which the Air Leakage Target for a project is realised**

Interfaces: Pro-Clima tapes & membranes, to manufacturers instructions, at floors (1) & eaves (3); Compriband & Illbrook tapes (2) around windows & doors



Roof: Cold roof, taped OSB forming upstairs ceiling, with service void & plasterboard

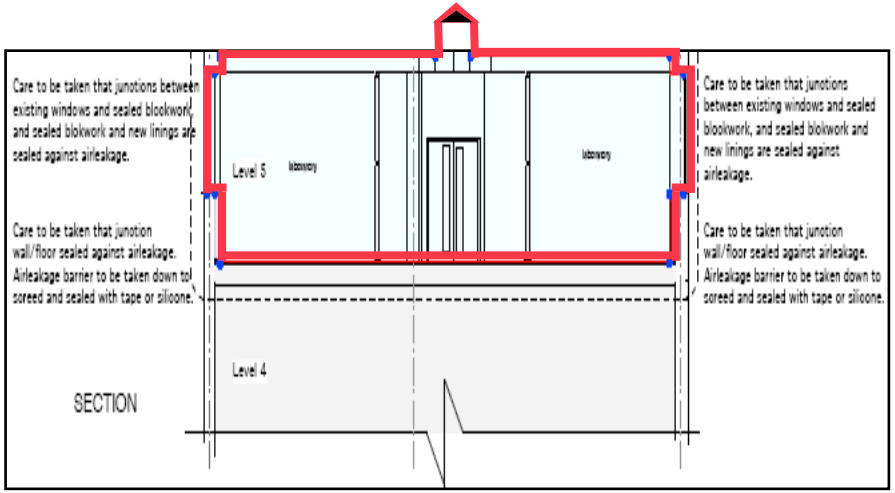
Walls: Timber frame with taped OSB behind Intello+ membrane; 140mm wood fibre insulation; plasterboard over

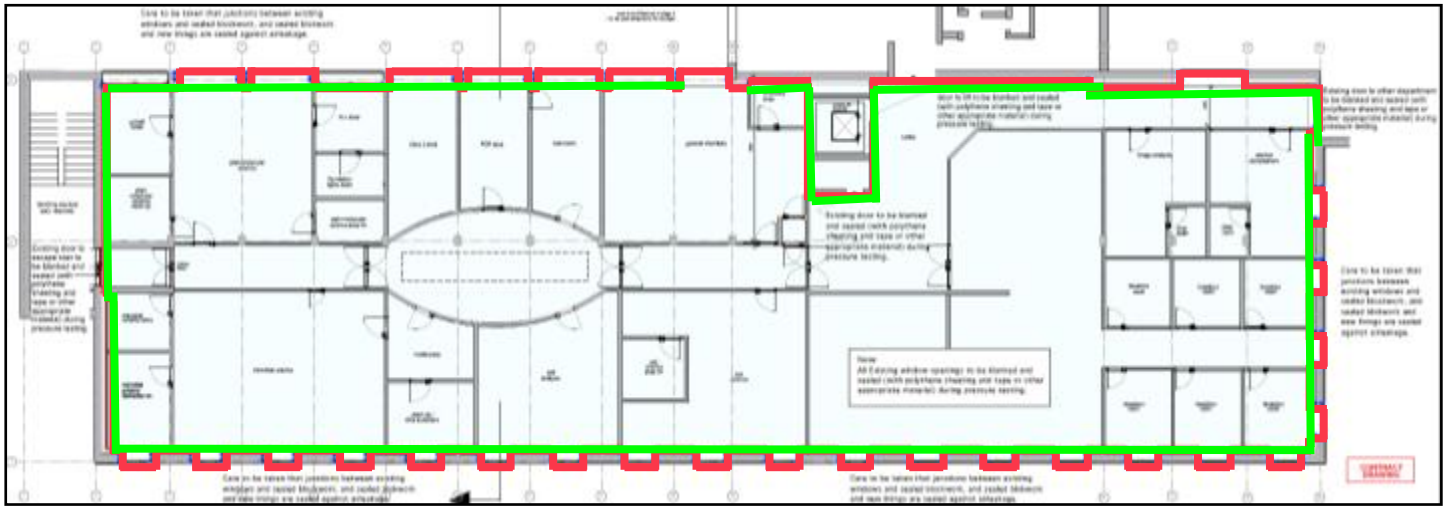
Penetrations: Sealed with Pro-Clima products according to schedule

Floor: screed over concrete floor

Step 3: Air Barrier Drawings

- Detail the air barrier plane in plans & sections
- Identify materials & means of sealing, work packages
- Controlled document, variations must be tracked





Red line – airtightness at the level of window openings;

Green line – below the window openings

Roles & Responsibilities

- Once design & specifications resolved;
- Airtightness is managed to success –
  - Key products are used correctly;
  - Sealing of critical elements is done at the appropriate time, is verified & recorded;
  - Zero tolerance for leakage, hence shoddy work is rejected, mistakes rectified;
  - More supervision required, with effective management of program & trades;

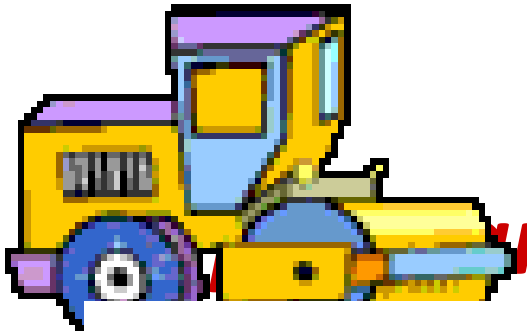
Hints & Tips

To successfully deliver Good Airtightness:

- **Get the design right – check for a continuous air barrier, ensure details are buildable;**
- **Invest in planning & preparation, training & record keeping;**
- **Tackle the culture – ensure that sub-contractors are prepared, site inductions, toolbox talks;**
- **Allow enough time**

Timings

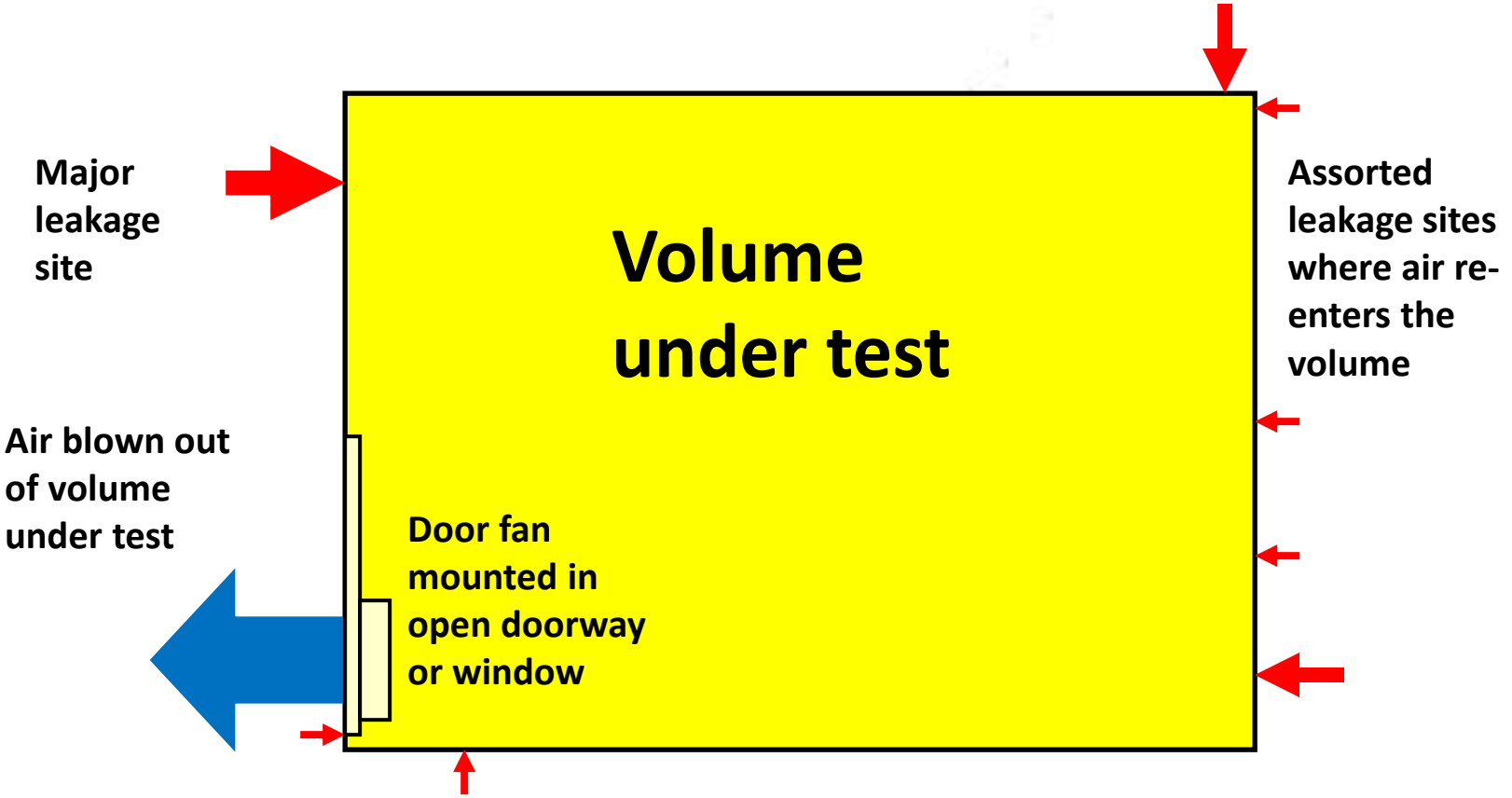
- Good airtightness takes longer;
- Cannot muddle through;
- Fundamental cause of many problems on major low-energy projects to date is:



m steamrollers quality

quality

Door Fan Testing - the Principle:

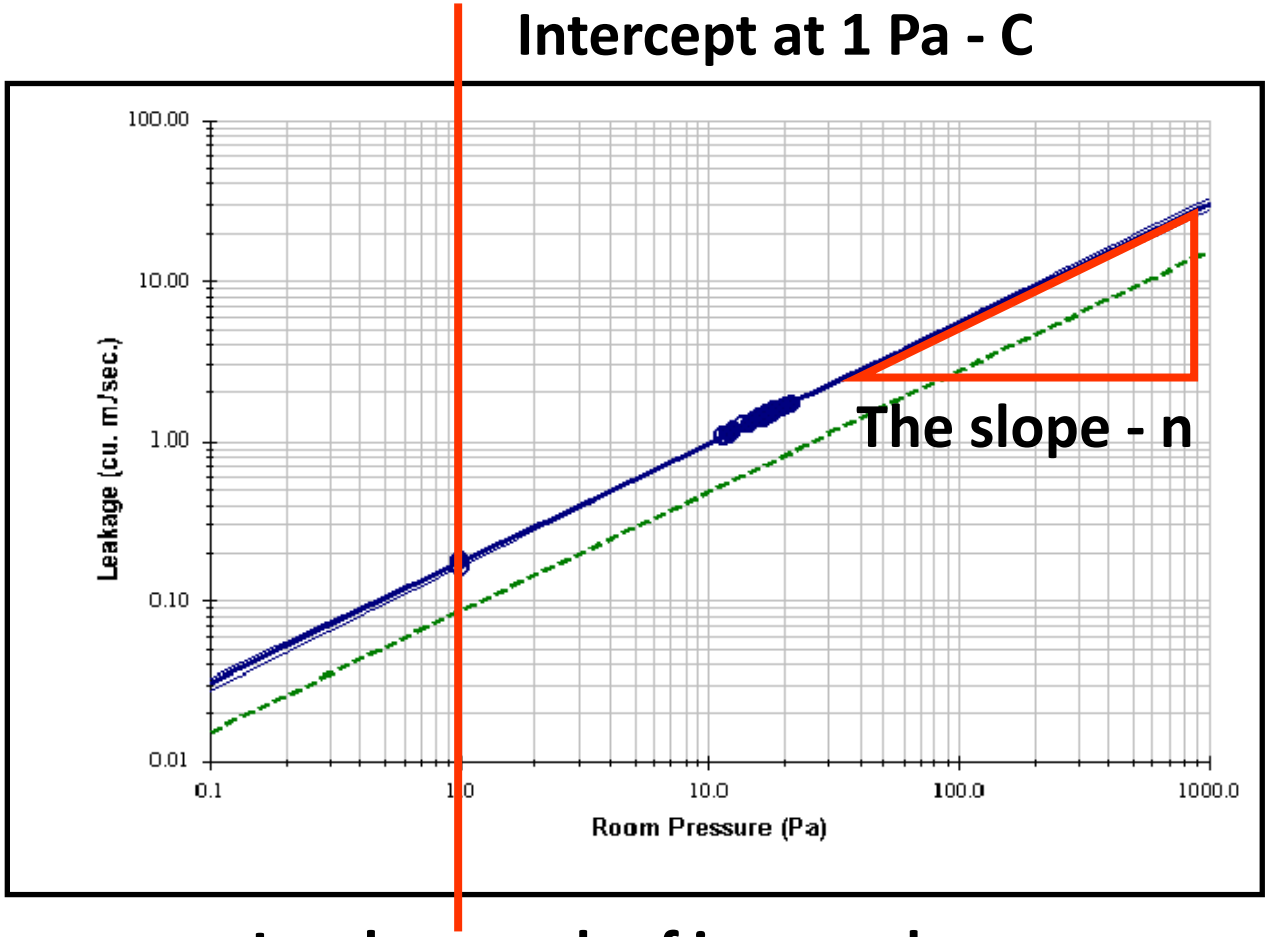


During a Door Fan test:

- Take readings of imposed pressure differential against airflow
- Make a least-squares curve fit
- Calculate the leakage characteristics
- Key characteristics:
  - Maximum & minimum values, number of readings
  - Airflow @ 50 Pa
  - Data consistency (r^2-value)
  - Flow exponent (slope, n-value)
  - Intercept at 1 Pa (C-value)

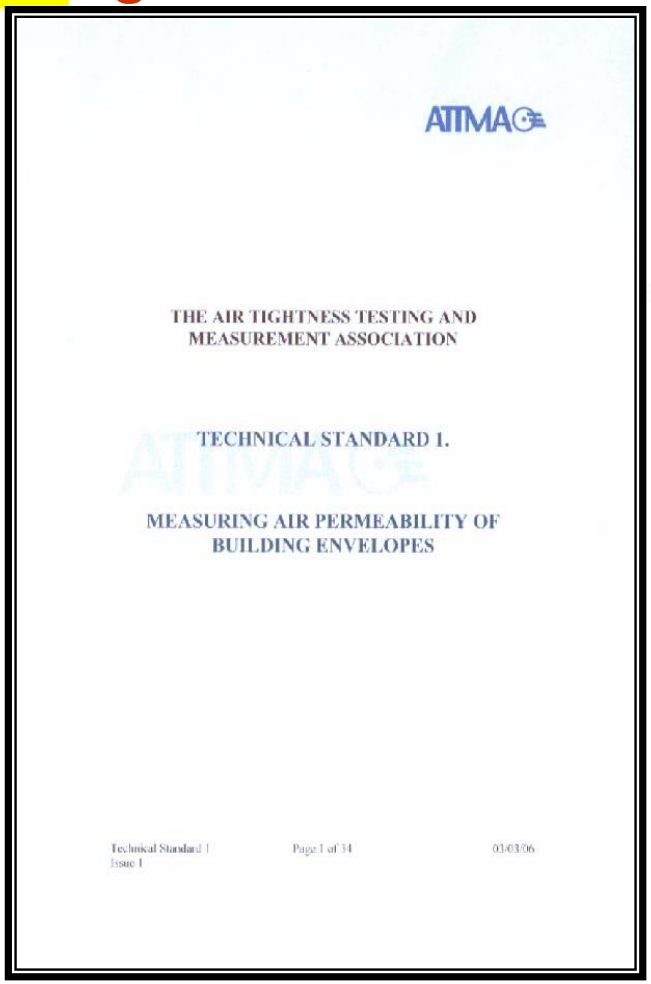
Graph:

Imposed pressure (x-axis) against airflow (y-axis)



Log-log graph of imposed pressure against airflow

Current Standard:



- The ATTMA (Air Tightness Testing & Measuring Association) Technical Standards:
- TSL1 (2016) for dwellings
- TSL2 (2010) for non-domestic
- TSL4 (2018) for low-energy & Passivhaus buildings
- Free download from:

  www.attma.org

  New editions are overdue

TSL1 & TSL2 Requirements:

- Test to BS EN 13829: 2001, with ATTMA-mandated enhancements
- All measurement equipment to be calibrated by a UKAS-accredited body, usually annually
- Maximum static pressure of 5 Pa, recommended maximum windspeed of 6 m/sec, 13.4 mph

Applying TSL1 & TSL2

- Calculating/ checking the envelope area is critical – issues with unheated plant rooms, escape stairs etc.
- HVAC plant is normally switched off & temporarily sealed
- External doors & windows closed, lift shaft doors closed - but not sealed
- Typically substantially simpler when applied to dwellings

TSL4 Requirements:

- Applied in conjunction with TSL1 (dwellings) or TSL2 (non-dwellings)
- For Passivhaus & AECB Building Standard
- Building must be complete – no temporary sealing except to ventilation systems
- Pressurisation and depressurisation tests
- Volume calculated in conformance with PHI requirements – room by room

Questions?

- The most stupid question is the unspoken one still in your head after you've left!
- Presentation available as download or by contacting me:
  - Paul Jennings, ALDAS
  - doorfanman@hotmail.com
  - Mob: 07866 948200

ALDAS Services

- Airtightness design reviews, to identify actual and potential air leakage weaknesses;
- Training for Airtightness Champions and other 1- & 2-day courses, including demonstration tests;
- On-site leakage audits of buildings prior to acceptance Air Tightness Testing;
- Sample testing of building sections;
- Pre- and post-improvement air leakage testing, acceptance testing
- Leakage investigations, including co-pressure tests, smoke tests & thermographic surveys