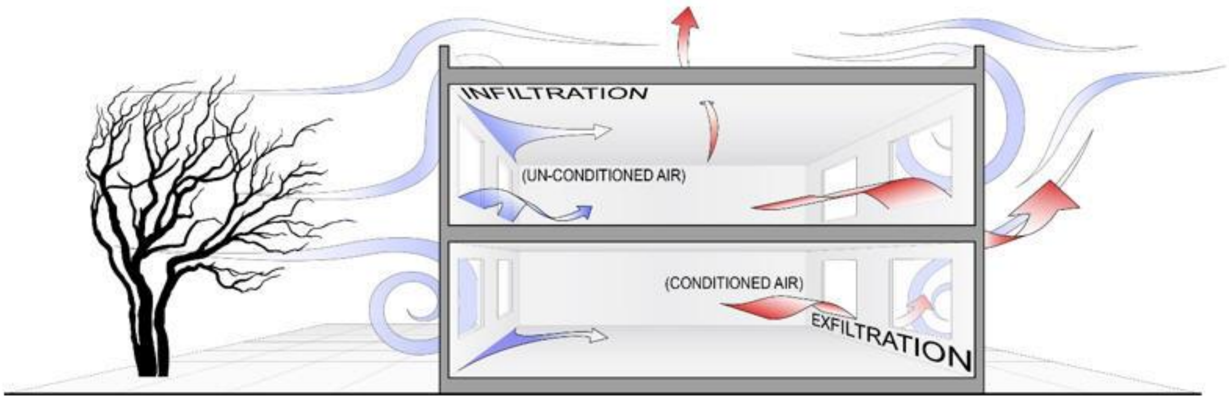
Infiltration – Air That Leaks Through a Building's Structure

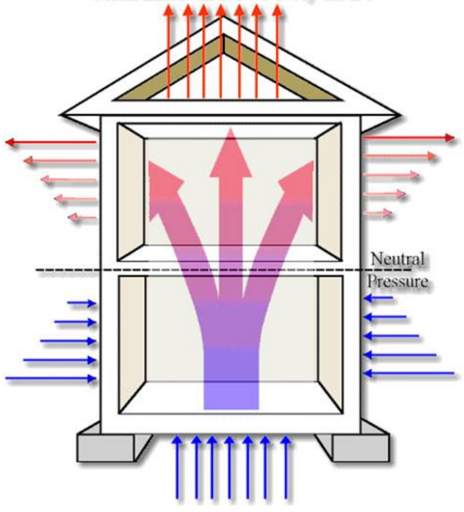
Buildings are not perfectly sealed. Even in super-buildings, where the builders have gone to extraordinary lengths to create as perfect a vapour barrier as possible, air still permeates and flows past the building envelope, through the occupied spaces and out the other side, whenever the wind blows.



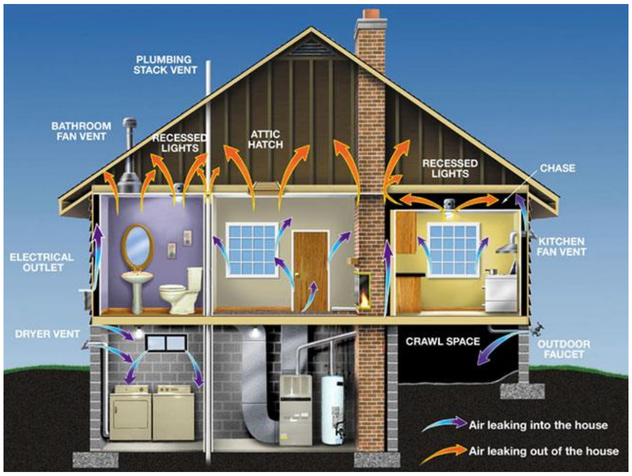
Infiltration is unconditioned air that enters the building from a variety of paths.

In past times people relied on infiltration to supply them with fresh, outdoor air. Traditionally there has not been a need to consider the problem of mechanically providing outdoor air to a space to keep the occupants healthy. Most buildings of the past had sufficient gaps around windows, doors, in the walls and roof, and at the foundation so that when the wind blew air would simply blow right through the building and keep the air fresh. On cold days, the buildings were often cold and drafty causing the heating costs to be extraordinary. In heated tall buildings, hot air inside the building would rise and flow out the upper floors of the leaky building and draw cold air in through the building structure at the bottom.

Stack Effect in a Two Story House



Modern buildings are sealed well but the change from virtually unsealed to super-sealed building envelopes has been a gradually change. For example, a 1911 home will have little insulation and have no vapour barrier. It will be leaky. A 1970's house will be better but far from perfect. It will have insulation in the walls and some homes will have a plastic vapour barrier. The doors and windows will be sealed somewhat better than the 1911 house but there will still be significant rates of infiltration. In the mid 1980's codes and standards began to immerge that enabled homes and commercial builds to become more energy efficient by reducing infiltration and increasing insulation. Today most buildings are built with a well sealed building enveloped and, to compensate for the lack of naturally flowing outdoor air through the occupied spaces, the codes demand that mechanical ventilation be installed to deliberately bring in outdoor air so that occupants remain healthy. In this course, we take the deliberate flow of outdoor air for granted and have used ASHRAE 62.1 many times to determine acceptable rates of outdoor air for a living and working space.



One of the major issues in assessing the heating and cooling demands of both residential and commercial buildings is assessing the rate at which outdoor air infiltration occurs and then dealing with it by providing more heat and more cooling. All that air that leaks through the building envelope needs to be heated in the winter and cooled in the summer.

There are several ways of assessing the rate at which infiltration occurs.

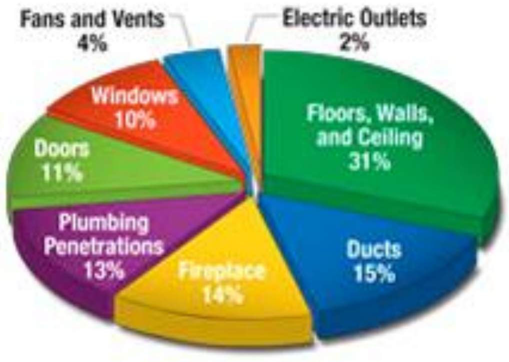
In larger commercial buildings, there is a good method, detailed by ASHRAE in their Fundamentals Handbook and elsewhere, called the Crack Method. It uses a method that assesses the air pressure differences between the outside and inside of the building, on all sides and on each floor. To calculate the infiltration rate the quality building construction is judged and the length and width of cracks in the building's structure are tabulated (around doors and windows, at the foundation, in the structure, etc). From the size of these cracks, and an assessment of the outside/inside air pressure differences that drives the air, infiltration rates are determined.

In smaller commercial buildings and residential buildings, a simpler method is used called the Air Changes Method. This is the one that will be detailed here.

The Air Changes Method is based on building studies that include old and new, poorly built and well sealed. Based on this work, and some judgement on the part of the designer, rates of infiltration can be assessed in Air Changes Per Hour. One limitation to this method is that it should only be applied to the assessment of heating and cooling loads for rooms and spaces that have an outside wall (perimeter spaces). The Air Changes Method should not be applied to interior spaces that do not have any outside walls.

The next page shows a table used to assess Infiltration ACH and an example follows.

In mid-century buildings (1930's, 40's, 50's, 60's and 70's) typical locations of infiltration of air leaks are illustrated in the pie chart.



Estimated Overall Infiltration Rates for Small Buildings

Part A. Construction Types

Construction Type	Description
Tight	Good multifamily residential construction with close-fitting doors, windows, and framing is considered tight. New houses with full vapor retarder, no fireplace, well-fitted windows, weather-stripped doors, one-story, and less than 1500 ft^2 (140 m^2) floor area fall into this category.
Medium	Medium structures include new two-story frame houses or one-story houses more than 10 years old with average maintenance, a floor area greater than 1500 ft^2 (140 m^2), average-fit windows and doors, and a fireplace with damper and glass closure. Below-average multifamily construction falls in this category.
Loose	Loose structures are poorly constructed single and multifamily residences with poorly fitted windows and doors. Examples include houses more than 20 years old, of average maintenance, having a fireplace without damper or glass closure, or having more than an average number of vented appliances. Average manufactured homes are in this category.

Part B. Design Infiltration Rate (ACH) for Winter: Indoors 68°F (20°C); Wind Speed = 15 mph (6.7 m/s)

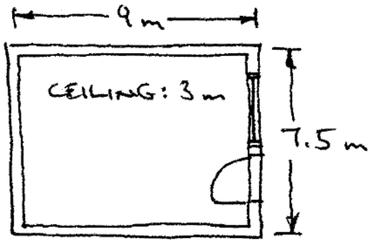
	Winter Outdoor Design Temperature									
Construction	°F: 50	40	30	20	10	0	−10	−20	−30	−40
Type	°C: 10	4	−1	−7	−12	−18	−23	−29	−34	−40
Tight	0.41	0.43	0.45	0.47	0.49	0.51	0.53	0.55	0.57	0.59
Medium	0.69	0.73	0.77	0.81	0.85	0.89	0.93	0.97	1.00	1.05
Loose	1.11	1.15	1.20	1.23	1.27	1.30	1.35	1.40	1.43	1.47

Part C. Design Infiltration Rate (ACH) for Summer: Indoors 75°F (24°C); Wind Speed = 7.5 mph (3.4 m/s)

	Summer Outdoor Design Temperature					
Construction	°F: 85	90	95	100	105	110
Type	°C: 29	32	35	38	41	43
Tight	0.33	0.34	0.35	0.36	0.37	0.38
Medium	0.46	0.48	0.50	0.52	0.54	0.56
Loose	0.68	0.70	0.72	0.74	0.76	0.78

INFILTRATION RATE AND EXTRA HEAT REQUIRED

TAKE OUR 'BUILDING HEAT EXAMPLE' ...



PLAN VIEW

CONSTRUCTION TYPE: MEDIUM

SEASON: HEATING, −1°C OUTSIDE

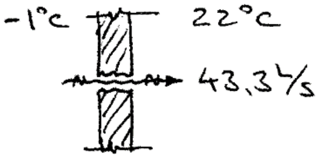
∴ INFILTRATION ACH = 0.77

RECALL: $\dot{Q}_I = \frac{\text{ROOM VOLUME} \times \text{ACH}}{3.6}, \frac{L}{S}$

ROOM VOLUME = $7.5 \times 9 \times 3 = 202.5\ m^3$

$$\therefore \underline{\dot{Q}_I} = \frac{202.5 \times 0.77}{3.6} = \underline{43.3\ L/s}$$

NOW HOW MUCH EXTRA HEAT IS REQUIRED TO WARM THE AIR THAT LEAKS IN FROM THE OUTSIDE.

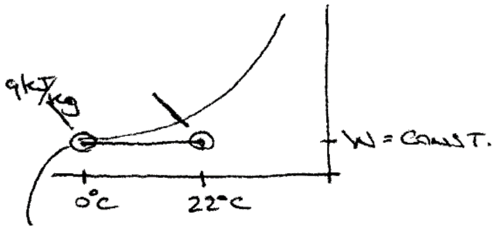


LOOKING AT THE PSYCHROMETRIC SUMMARY HANDOUT, HEATING © ...

$$\dot{q}_{\text{HEATING}} = \dot{m}_I (h_{\text{WARM}} - h_{\text{COOL}})$$

ALSO $\dot{m}_I = \frac{\dot{Q}_I}{v_{\text{ROOM}}}$

USING THE PSYCHROMETIC CHART ...



WINTER OUTDOOR IS USUALLY 90 − 100% rh

OUTDOOR: $h_{\text{COOL}} \cong 9\ kJ/kg$ { AN EYE BALL ESTIMATE - TAKE A LOOK -

INDOOR: $v_R = 0.841\ m^3/kg$

$h_{\text{WARM}} = 31.5\ \frac{kJ}{kg}$

SO NOW ... $\dot{m}_I = \frac{\dot{Q}_I}{v_{\text{ROOM}}} = \frac{43.3 \times 10^{-3}\ \frac{m^3}{s}}{0.841\ m^3/kg}$

$\dot{m}_I = 0.051\ kg/s$

AND $\dot{q}_{\text{HEATING}} = (0.051)(31.5k - 9k)$

$= 1.15\ kW$

$\boxed{\dot{q}_{\text{HEATING}} = 1150\ \text{WATTS}}$

GOOD HEAVENS!
OUT TRANSMITTED HEAT LOSS RATE WAS ONLY 566 WATTS.

INCLUDING INFILTRATION INCREASES THE HEATING DEMAND BY MORE THAN 2 TIMES.

LETS SEAL THIS BUILDING BETTER ('TIGHT' → 0.45ACH & 670 WATTS)