Building envelope

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Definition of Building envelope

Buildings are designed and constructed to provide shelter from the weather and normally house conditioned , habitable spaces for occupants. The building envelope is an assembly of components and materials that separate the conditioned indoor environment from the outdoor environment. The envelope typically includes the **foundation**, **walls**, **windows** , **doors** , and **roof**.

Performance requirements for the building envelope

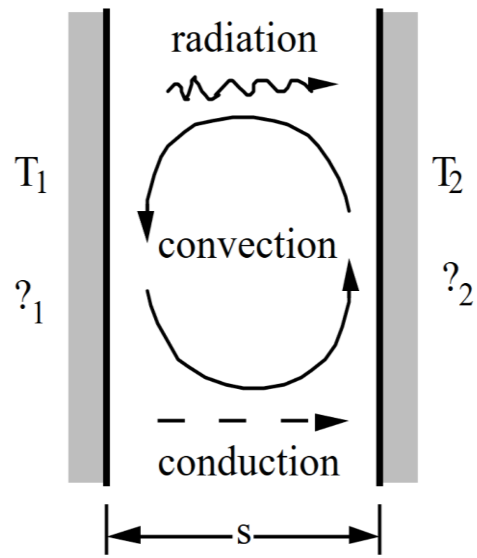
1. Control heat flow
2. Control liquid water penetration with rain as the most important source
3. Control water vapor flow
4. Control light, solar, and other radiation
5. Control noise
6. Control fire
7. Provide strength and rigidity against outside influences (some-times structural)

Heat Transfer & Thermal Envelope

Heat always flows from the wormer side of the building shell to the colder side.

Heat Transfer Mechanisms

- Conduction
- Convection
- Radiation (is a critical consideration on roofs especially)



Heat Transfer & Thermal Envelope

- **Conduction** is heat flow through a material from hot to cold. This phenomenon explains why the handle on a stove pot becomes hot, and why people insulate walls. Conductivity depends on the materials used in the building shell. Insulation slows, but does not stop, heat flow through the walls and roofs. R-value indicates how well am insulation barrier impedes heat flow – the larger the R-value, the less heat flows through a wall or roof by conduction in a given amount of time.
- **Convection (Infiltration)** is a heat flow via air movement. This phenomenon explains why occupants feel cold when the door is open on a winter day, and why caulking small cracks around windows improves comfort.
- **Radiation** is heat flow over a distance from hot to cold way the Sun's heat reaches Earth. Building occupants use windows shades to block radiation

Infiltration

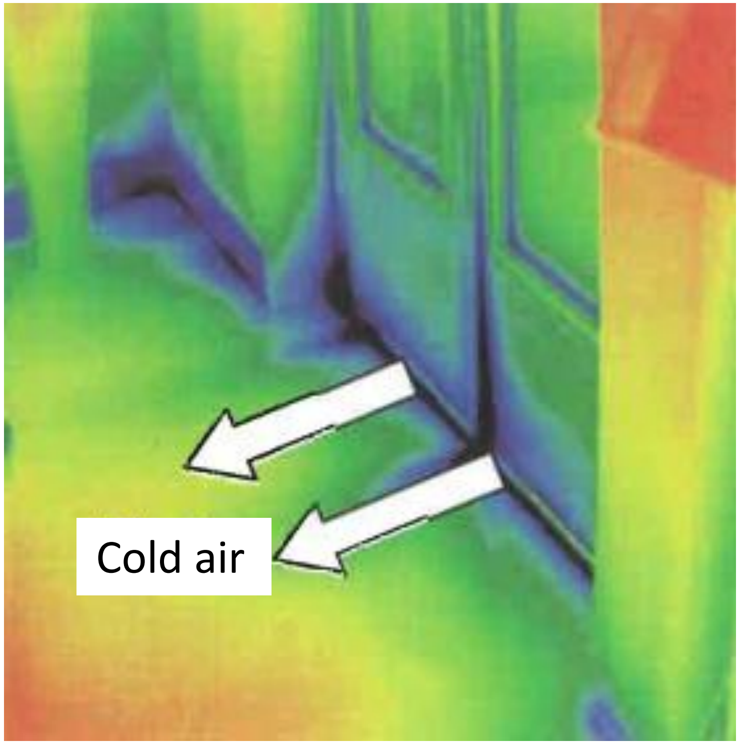
- In older buildings, heat often leaks through breaks in insulation or around windows. This infiltrating can greatly reduce the isolation's effectiveness, so R-values alone do not fully describe the energy efficiency of a wall or roof.
- All buildings allow some level of uncontrolled airflow through the building envelope. Infiltration paths include seals around operable windows, cracks or seams in exterior panels, doorjambs, and shell penetrations.
- Air flowing into or out of these leakage paths is driven by pressure difference caused by HVAC equipment between the inside and outside of the building, between windward and leeward sides of the building, and between upper and lower floors (natural convection, commonly called the chimney effect).

Infiltration

- In general, a building envelope should meet recommended infiltration standards. A frequent result of infiltration problems is an increase in building heating, cooling, and/or electrical loads (when, for example, occupants may bring in space heater of fans)
- In addition, the escape of conditioned air forces the air-handling system to work longer and heater to provide the required space temperature.

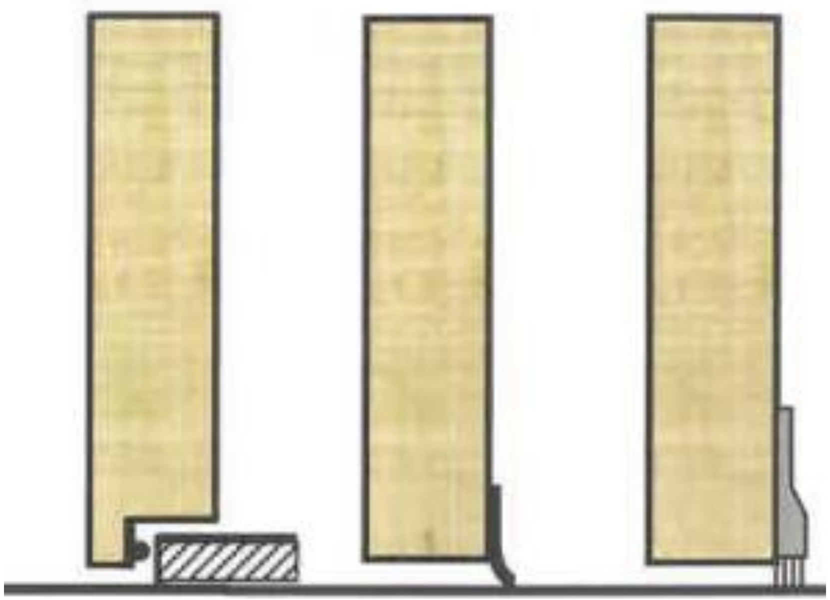
Reduction Air Infiltration

- To reduce air infiltration, take the following steps:
- Tighten the existing building by locating all air leaks in windows, doors, and roofs.
- Seal with appropriate materials and techniques such as stripping on doors; sealing and caulking on windows; and proper insulation distribution in walls, ceilings, and roofs.



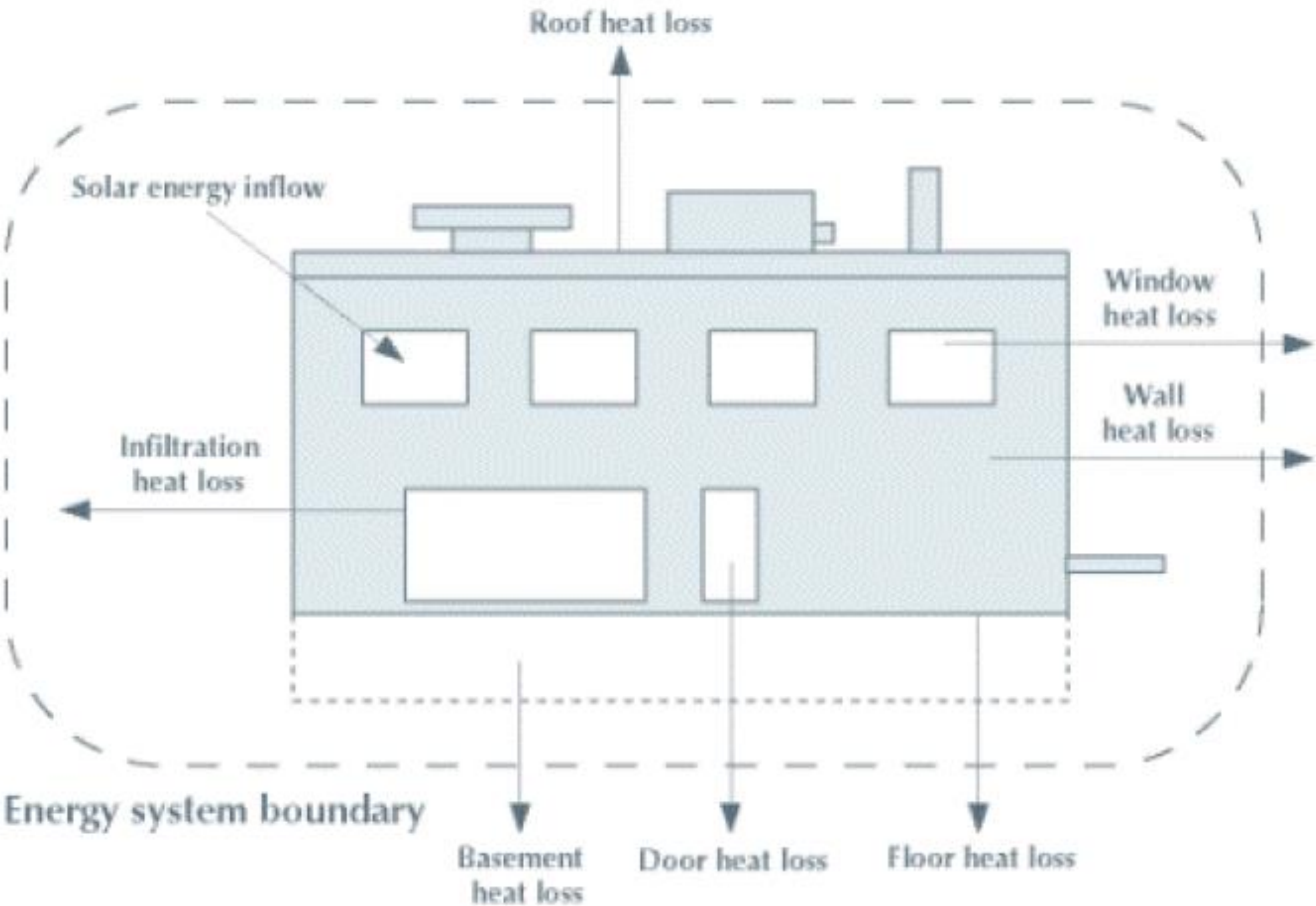
Reduction Air Infiltration

- Encourage the use of revolving doors in buildings so equipped. Revolving doors significantly reduce drafts and the loss of conditioned air.
- Calibrate automatic doors to minimize air loss from the building envelope.
- Reducing infiltration will result in a reduction in heating and cooling loads. Typical savings for a large office building range up to 5 percent of heating and cooling costs.



Reducing infiltration of doors using rubbers and brushes

Tightening the Envelope



Heating load and cooling load for a building

Heating and cooling load is the heating and cooling energy required for building to maintain interior air temperature.

Calculating of heating and cooling load:

Cooling requirement (or negative of the heating requirement) = Solar gains + internal gains ± infiltration heat loss ± ventilation heat loss ± heat losses through roof, walls, floor, windows & doors.

Building Envelope: Thermal Conductance

Heat losses through roof, walls, floor, windows & doors:

Heat loss = U-value × Area × time × ($T_{int} - T_{ext}$)

U-value: apparent heat transfer rate per unit area

Radiation

- Solar Radiation. Solar radiation can have an enormous influence on heating and cooling requirements.
- The sun often makes perimeter spaces uncomfortable hot, creates glare, and fades fabrics. Handled properly, however, this incoming solar radiation can reduce lighting loads.
- Reducing solar gain (heating caused by solar radiation) without sacrificing all of the light available for daylighting offers very profitable opportunities for cooling-load reductions and energy savings.
- Windows films, window shading, and high performance windows can reduce heat flow through a building’s windows.

FENESTRATION

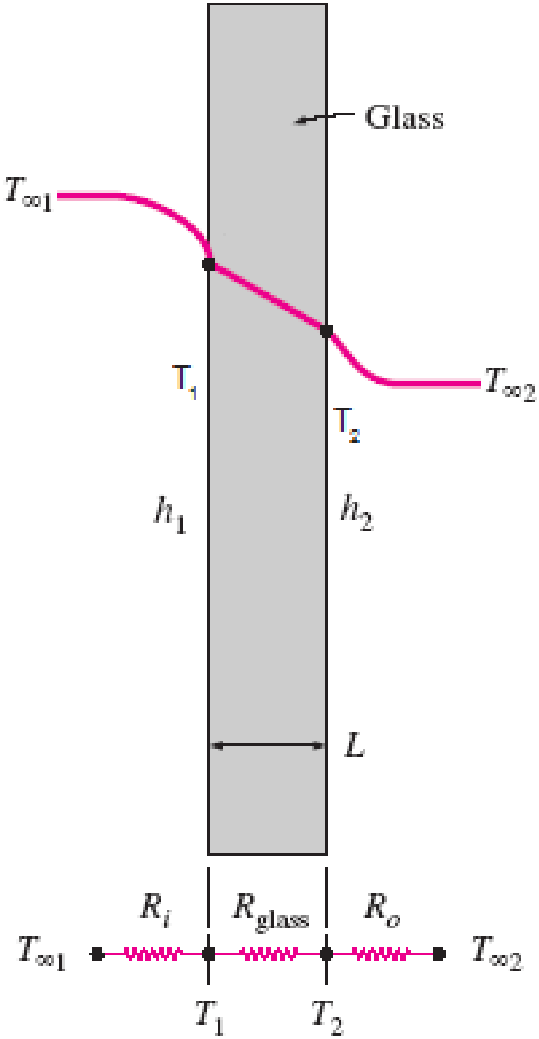
FENESTRATION is an architectural term that refers to the arrangement, proportion, and design of window, skylight, and door systems in a building. Fenestration can serve as a physical and/or visual connection to the outdoors, as well as a means to admit solar radiation for natural lighting (daylighting), and for heat gain to a space. Fenestration can be fixed or operable, and operable units can allow natural ventilation to a space.

FENESTRATION

- Fenestration affects building energy use through four basic mechanisms: thermal heat transfer, solar heat gain, air leakage, and daylighting.
- The energy effects of fenestration can be minimized by
  (1) using daylight to offset lighting requirements.
  (2) using glazing and shading strategies to control solar heat gain to supplement heating through passive solar gain and minimize cooling requirements.
  (3) using glazing to minimize conductive heat loss.
  (4) specifying low-air-leakage fenestration products.
  (5) integrating fenestration into natural ventilation strategies that can reduce energy use for cooling and fresh air requirements.

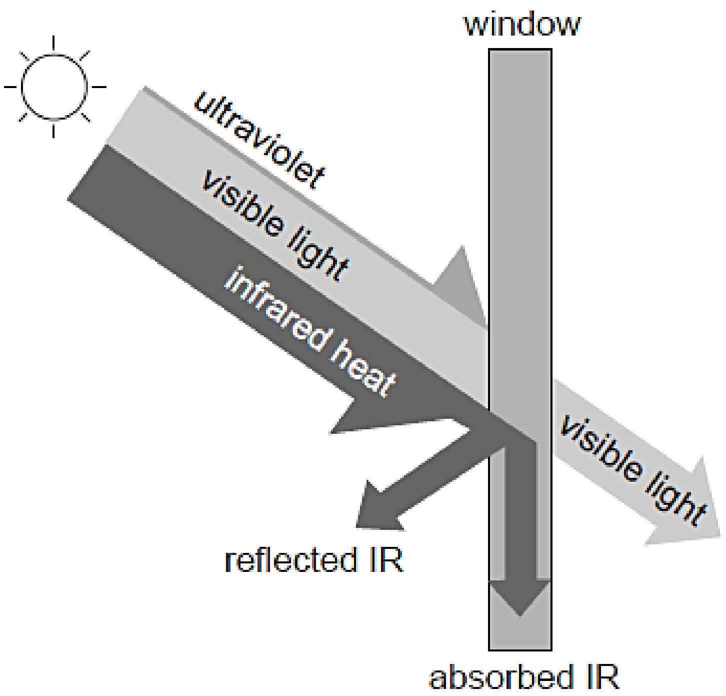
Windows

Windows typically have a very low R-value.



Windows Options

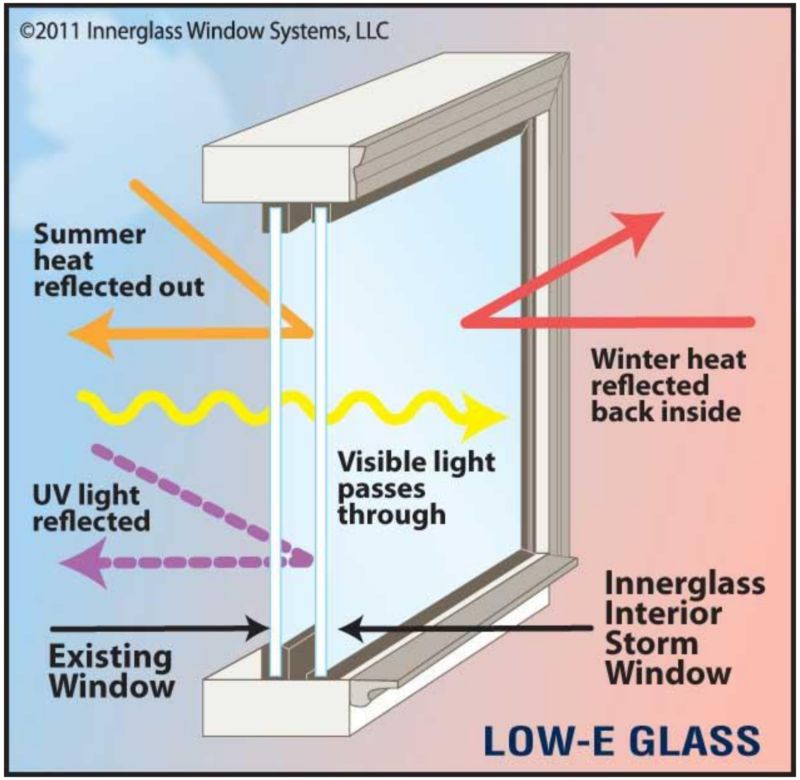
Spectrally selective glass. This type of glass can maximize or minimize solar gain and shading depending on the chosen selectivity.



Spectrally Selective Glazing

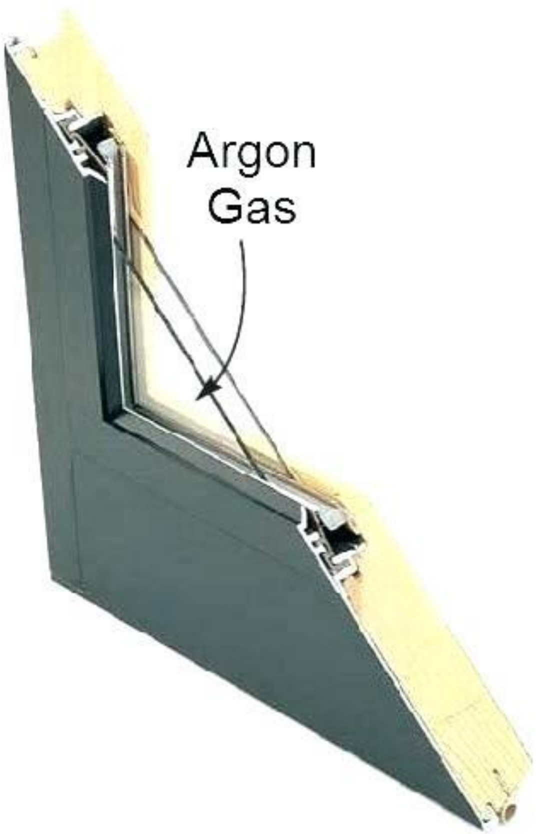
Windows Options

Double-glazed, low-e system. Layers of low-e film are stretched across the interior air space between glass panes, and windows with this feature offer R-values as high as 8.



Windows Options

Gas filled windows. Using argon or krypton gas between glass panes, this technology minimize the convection currents and conduction through the glass-filled space, reducing overall heat transfer through the window.



Windows Options

Electrochromic windows. When integrated with a daylighting control system, these windows can preserve the view outside while varying their tint to modulate transmitted light, glare, and solar heat gain. Sensors that adjust tint can automatically balance comfortable lighting with energy efficiency.

FENESTRATION COMPONENTS

Fenestration components include:

1. Glazing material, either glass or plastic;
2. Opaque door slabs;
3. Shading devices such as louvered blinds, drapes, roller shades, and awnings.

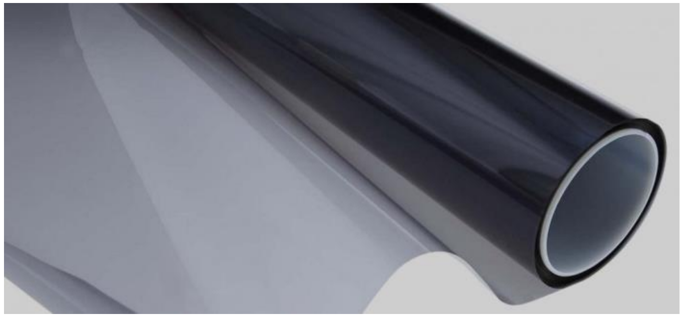
Roll Out Patio Window Door Outdoor Awning

Effective Building Shading

Interior shading. Venetian blinds and other operable shades are low-cost and effective solutions for keeping out sunlight. Shades can be installed between two panes of window glazing to automatically open and close shades in response to light.

Window Film

- Window films are thin layers of polyester, metallic coating, and adhesives that save energy by limiting both the amount of solar radiation passing through the window and the amount of internal heat escaping. Window films can be retrofitted to existing windows to reduce heat gain and provide low-cost cooling load reduction and generally last 5 to 15 years.
- Low-emissivity (low-e) coatings. Low-e coatings insulate better than bare windows, while allowing as much solar heat gain as possible.



Window Film Heating Reduction

- Performance of window films are measured by a shading coefficient, SC.
  - SC = 0 means no heat passes
  - SC = 1 means it does nothing to stop heat
- Therefore, the fractional heat flow reduction sue to the window film is given by (1-SC)

Shading Coefficient Example

Savings from window film can be found using (1-SC).
The annual solar heat gain foe windows facing wet in building has been calculated to be 165,000 kJ/m2. If a shading film with shading coefficient 0.6 can be applied to these windows at a cost of $20.00 per square meter, calculate the simple payback . The COP of the air conditioner is 2.7 and the electricity costs $ 0.06 per kWh.

- 165,000 kJ/m2/yr = 45.833 kWh/m2/Yr
- Reduction heat gain = (0.4) * 45.833 kWh/m2/Yr = 18.333 kWh/m2/Yr
- Reduction in Electrical consumption = heat reduction / COP
- = 18.333 / 2.7 = 6.79 kWh
- Cost of saving = 0.06 * 6.79 = $ 0.407
- Pbp = $ 20.0 / $ 0.407 = 49 years.

Roofing Options

- Measures that can be employed to reduce heat flow into and out of a building through the roof include roof insulation, cool roofs, and green roofs.
- Much of a building's heat losses and gains occur through the roof , so there are often significant energy-saving opportunities related to roof efficiency.

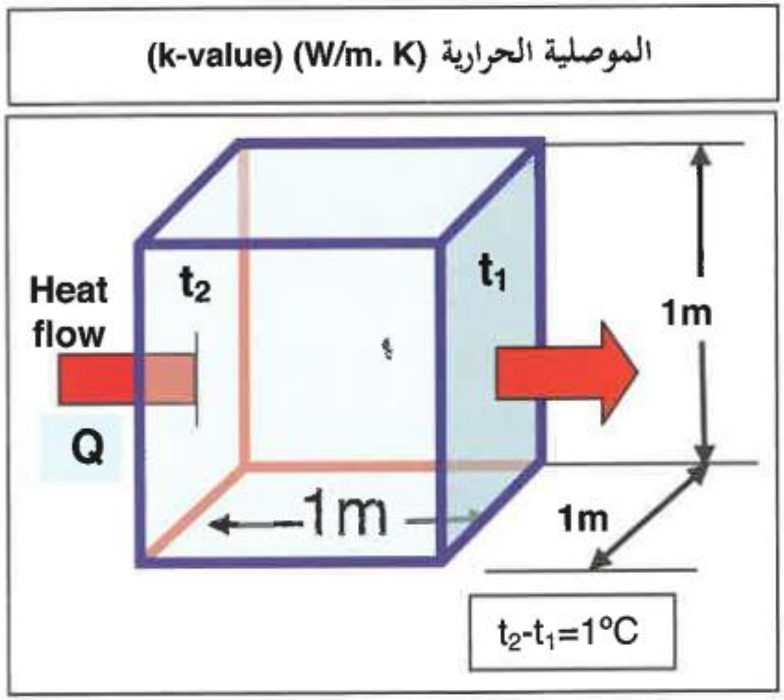
Cool Roofs

- Cool roofs feature a highly reflective outer surface that reduces the amount of heat conducted through the roof.
- Benefits of cool roofs include:
- Downsized air conditioning equipment. A cool roof can reduce peak cooling demand up to 40% in warm climates.
- Extended roof life. Cool roofs tend to last longer because they are less susceptible to thermal expansion and contraction.
- Reduced heat island effect. Non-reflective roofs can heat the air around them in a process known as the heat island effect. This can raise the cooling demands of buildings contributing to smog, elevated ambient temperatures, and associated health problem.

Thermal insulation

Thermal conductivity

The thermal conductivity of a material is a measure of its ability to conduct heat. It is the rate at which heat passes through a specified material, expressed as the amount of heat that flows per unit time through a unit area with a temperature gradient of one degree per unit distance.

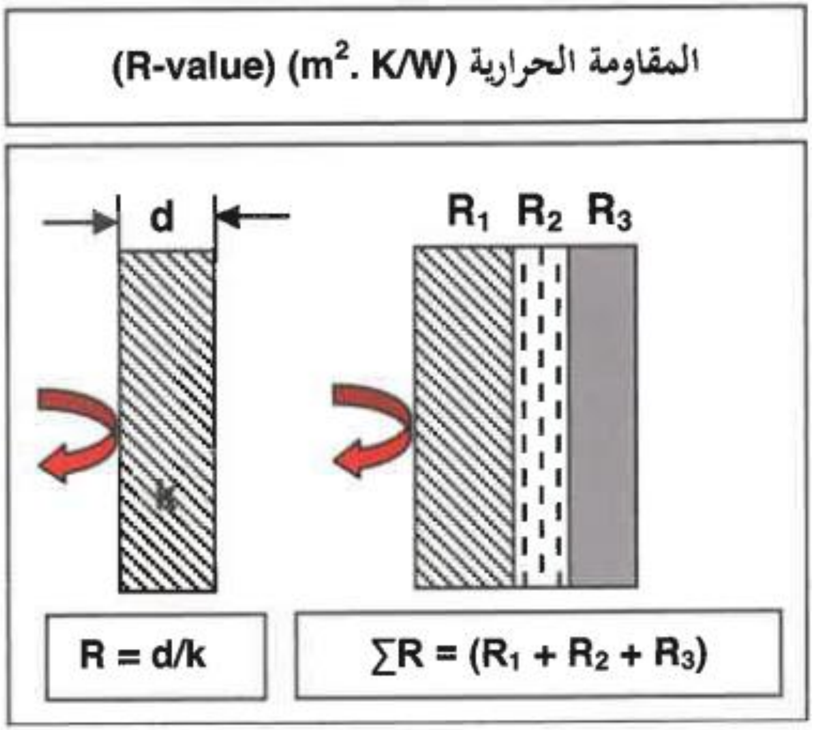


Thermal conductance

Thermal conductance is defined as the quantity of heat that passes in unit time through a plate of particular area and thickness when its opposite faces differ in temperature by one kelvin. For a plate of thermal conductivity k, area A and thickness L, the conductance is $k A / L$, measured in $W \cdot K^{-1}$.

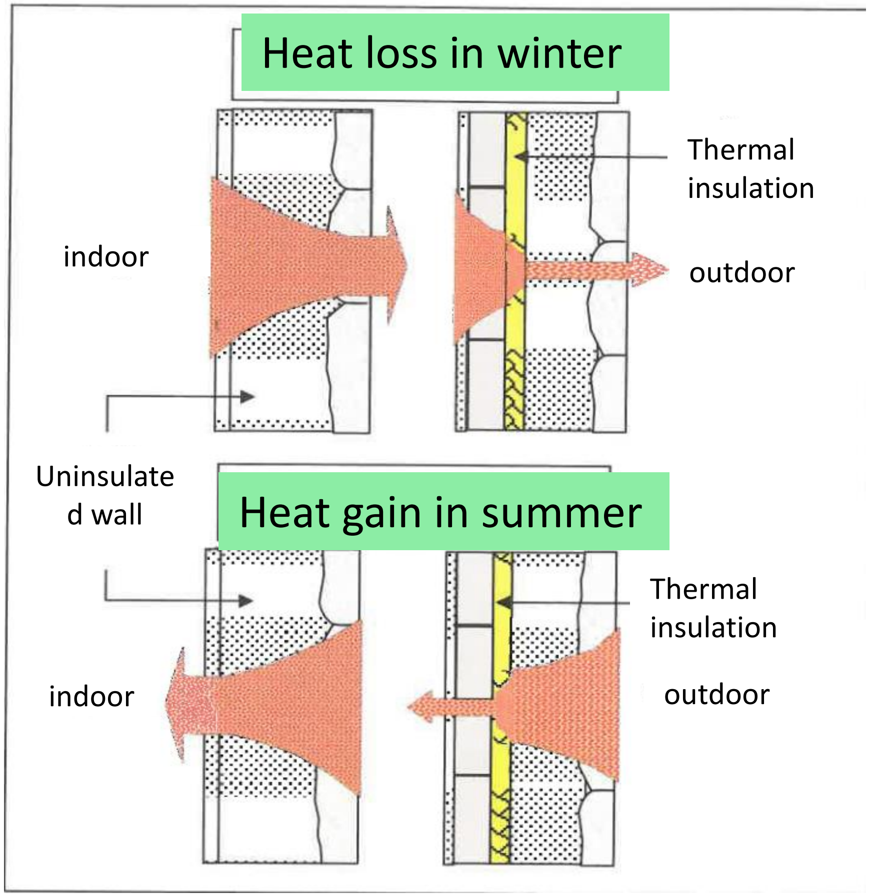
Thermal resistance

Thermal resistance is a heat property and a measurement of a temperature difference by which an object or material resists a heat flow. Thermal resistance is the reciprocal of thermal conductance.



Effect of adding thermal insulation

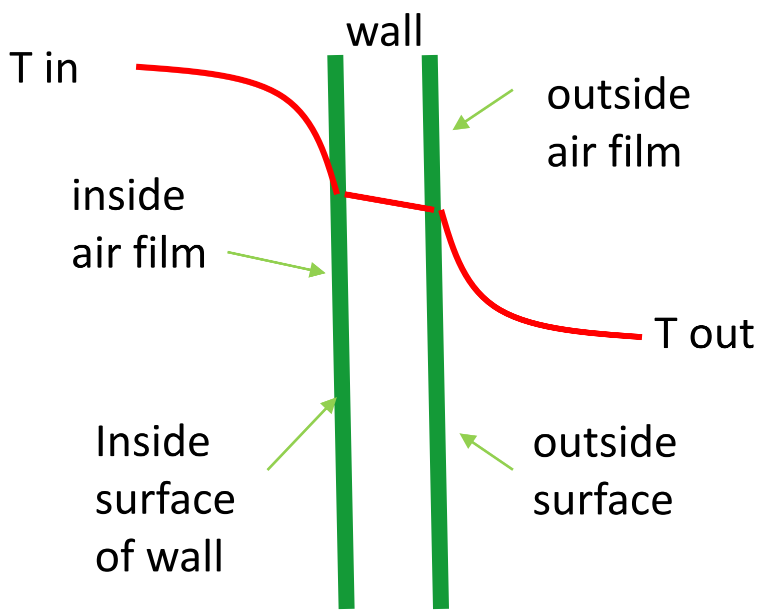
- Energy saving is achieved due to reducing of heating and cooling loads
- Increasing the level of thermal comfort of the building.
- Protect the building from external environment conditions and thermal stresses and the resulting damage.
- Avoiding of internal condensation and damps.



Damps on wall and ceiling surfaces

Heat Loss and gain

- Heat is lost and gained through walls and ceilings.
- Consider a two cm (20 mm) plywood wall.



Basic heat flow equations

- Consider heat losses through walls and ceilings

$$q = \frac{A \times \Delta T}{\sum R} \quad (\text{W})$$

- Heat loss is proportional to the area A and the temperature difference ΔT between inside and outside.
- $\sum R$ is the sum of the resistances of everything that resists heat flow.

$$\sum R = R_{inside\ air\ film+}\ R_{plywood+}\ R_{outside\ air\ film} \qquad \frac{m^2\ {}^\circ C}{W}$$

Basic heat flow equations

- The equation often is written
- $q = U \times A \times \Delta T$ (W)
- Where U is the overall thermal conductance
- $U = \frac{1}{\sum R} = \frac{1}{R_{total}} \qquad \frac{W}{m^2\,°C}$

Surface Air Film Resistance values

Surface Resistance	Direction of heat flow		
(m^2K / W)	Upwards	Horizontal	Downwards
Rsi	0.10	0.13	0.17
Rse	0.04	0.04	0.04

Source : EN ISO 6946 : 2007 Building components and building elements - Thermal resistance and thermal transmittance - Calculation method.

Wall and Insulation Resistances

- R can be obtained from the conductance C, given for a specified thickness of material,

$$R = \frac{1}{C}$$

- If the conductivity ***k*** is given, ***R*** can be calculated knowing k and the material thickness t in meter.

$$R = \frac{1}{k}$$

Conductance's and conductivities

Material	Description	K value	C or U
Building boards	Gypsum 12.7 mm	0.16	12.6
	Plywood 19 mm	0.12	6.3
	Concrete block 200 mm	1.1	55
Insulation materials	Fiberglass	0.036	
	Mineral wool	0.039	
	polystyrene	0.04	

Basic Heat Flow Equations

- How could we reduce the heat flow
- Often the answer is insulation – a simple and inexpensive way of adding more resistance to the denominator of the equation

$$q = \frac{A \times \Delta T}{\sum R} \quad (\text{W})$$

Basic Heat Flow Equations

- Temperature varies with time of day and season, so we often resort to this heat conduction equation

$$Q = U \times A \times DD \times 24 \text{ (Wh/yr)}$$

- Where DD can be HDD or CDD, annual units are $\frac{°C\ day}{yr}$
- U × A is also known as the conduction part of the overall building load coefficient . Other parts including infiltration, ventilation and slab-on-grade factor.

Air Heat Flow Problems

- Q = m Δh [W] General
- Q = m Cp ΔT [W] Sensible heat only

- M = mass flow rate (kg/s)
- Δh = Enthalpy difference (kJ/kg)
- Cp = heat capacity (kJ/kg °C)
- ΔT = Temperature difference (°C)

Air Heat Flow Problems

- Air : Sensible heat only
- Q = LPS × $\frac{1.204\ kg}{m^3}$ × $\frac{0.001\ m^3}{L}$ × $\frac{1.006\ kJ}{kg\ °C}$ × ΔT
- Q = LPS × 1.2 × ΔT [W]

Air Heat Flow Problems

- Air : General

- $Q = LPS \times \frac{1.204\ kg}{m^3} \times \frac{0.001\ m^3}{L} \times \ \Delta h$

- $Q = LPS \times 1.2 \times \Delta h$ [W]

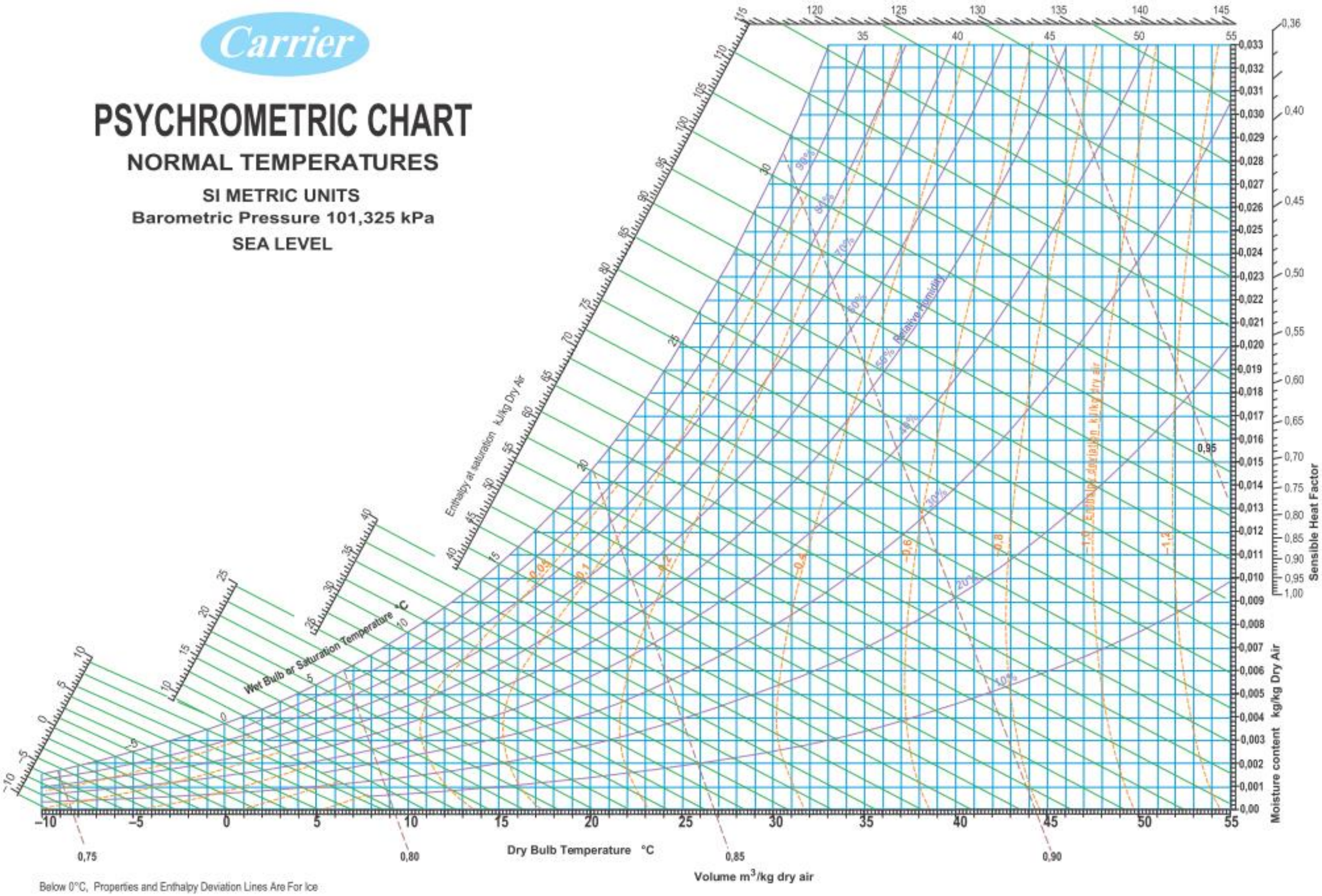
Water : Sensible Heat Only

- Q = LPS × $\frac{1000\ kg}{m^3}$ × $\frac{1\ m^3}{1000\ L}$ × $\frac{4.2\ kJ}{kg\ °C}$ × ΔT
- Q = LPS × 4.2 × ΔT [W]

The Psychrometric Chart

- The Psychrometric Chart graphically represents the steam tables for moisture in air at conditions we encounter in HVAC work.
- The Psychrometric Chart allows complex problems to be worked out easily, and provides a feel for common HVAC processes that we are interested in.
- The standard CARRIER Psych Chart has a horizontal axis for dry bulb temperature, and vertical axis for humidity ratio in kg of moisture per kg of dry air.
- Other parameters on the chart are: relative humidity, wet bulb temperature, enthalpy, specific volume, and saturation temperature.

The Psychrometric Chart



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