



Aalto University
School of Engineering

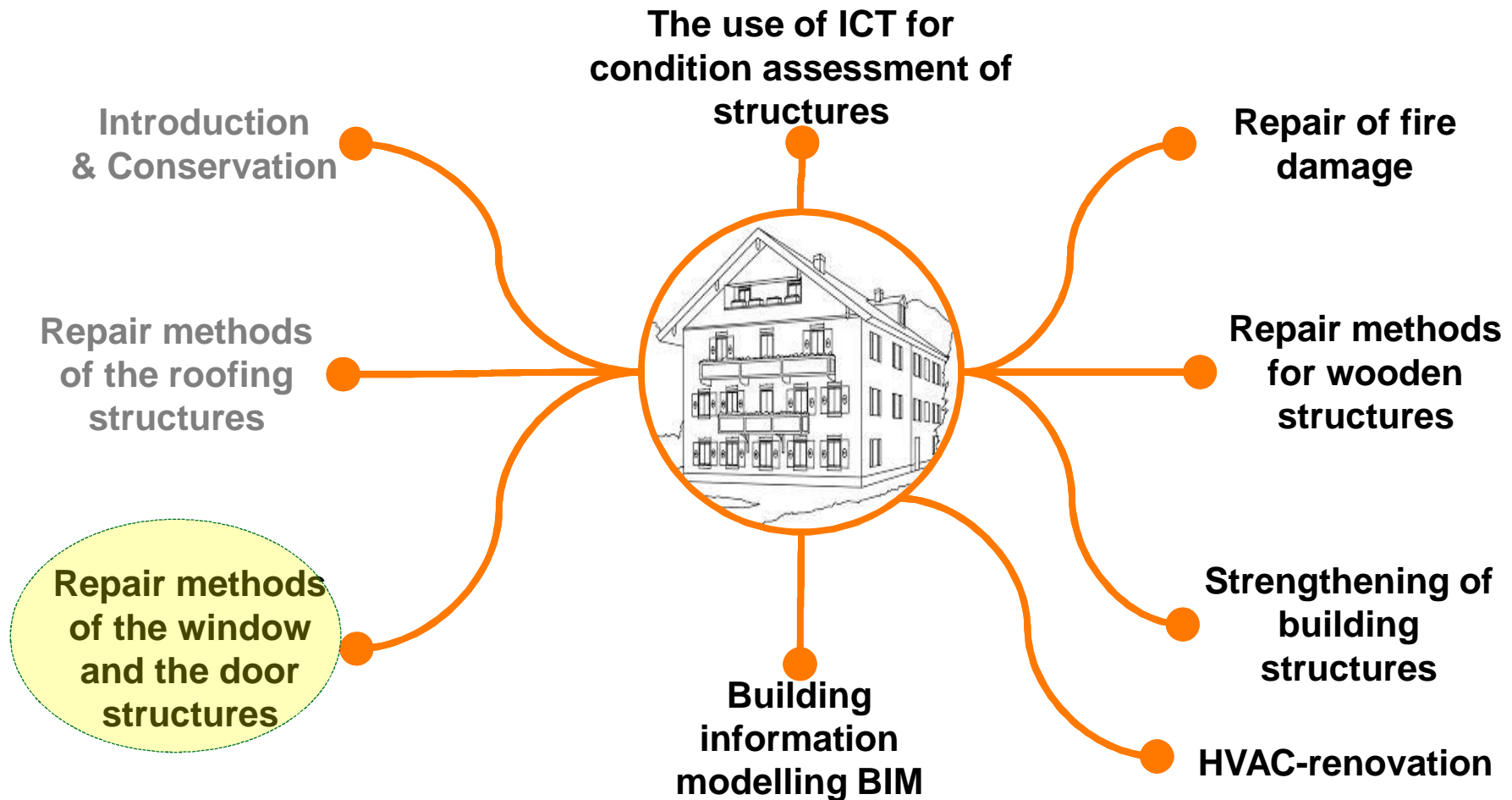
Rak-43.3313 Repair Methods of Structures, exercise
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Repairing Windows and Doors

Mon 07.03.2016

Course Content



Recommended readings

REPAIRING WINDOWS & DOORS

Online at:

http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/windows_doors.pdf

Energy-Efficient Windows and Doors

Online at:

http://www.uoxray.uoregon.edu/phys161/consumer_guide.pdf

Museovirasto

KORJAUSKORTISTO

Ikkunoiden korjaus

Online at:

<http://www.nba.fi/fi/File/2117/korjauskortti-8.pdf>

Outlines

- Introduction
- Windows and doors deterioration
- Windows and doors inspection
- Windows and doors repairing
- Energy-Efficient Windows and doors
- High-Performance Windows

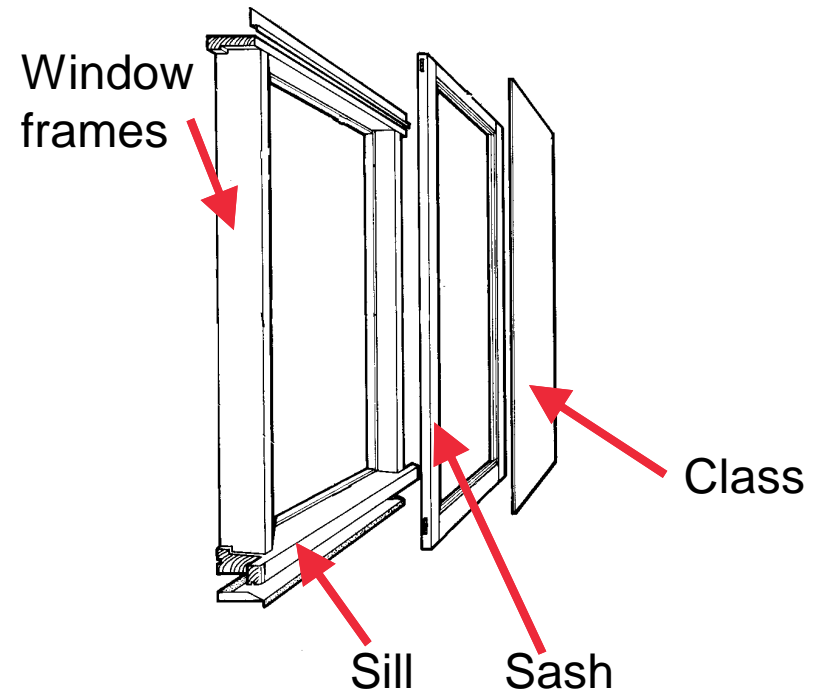
Window and doors

Introduction

Windows

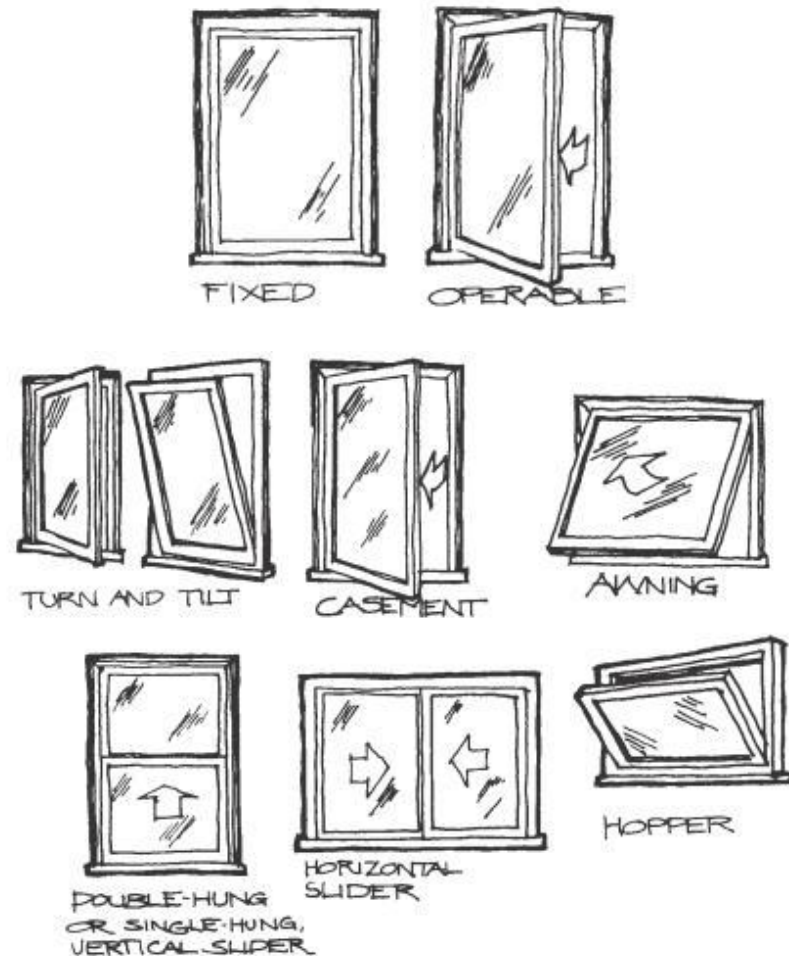
Building component (glazing) for closing an opening in a wall or pitched roof that

- **will admit light and**
 - **may provide ventilation,**
- including the frame of the window which is defined as the component forming the perimeter of a window, enabling it to be fixed to the structure.



Windows

- Two main types of windows
 - open “operable” windows
 - fixed windows
- Operable windows:
 - as awning, casement, hopper, horizontal slider, or tilt and turn windows.
- The opening part of operable windows is often referred to as a “sash” or “vent”
- The window frames can be made of wood, metal or vinyl.
- The transparent portion of the window is referred to as the “glazing”.

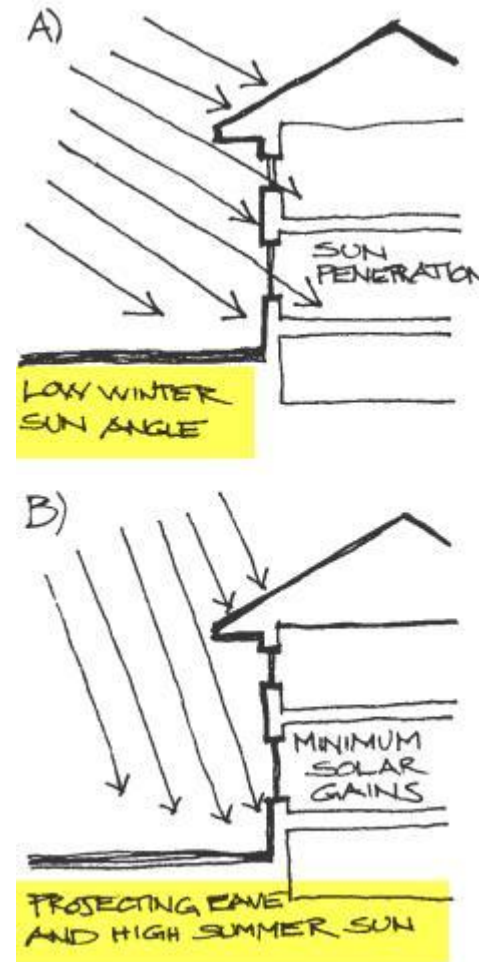


How windows perform?

How windows allow home to **gain energy** from the sun, and how they **affect energy loss** when the sun isn't shining

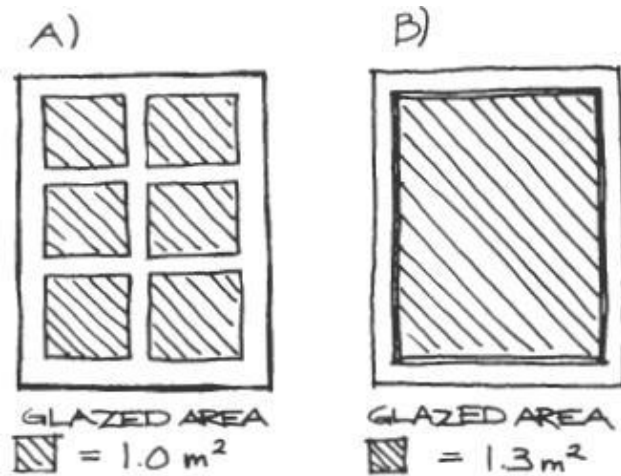
Factors Affecting Gains

- 1) placement and orientation
- 2) design of the window unit (and the amount of clear window opening)
- 3) the type of glazing used; and
- 4) the amount of interior and exterior shading.



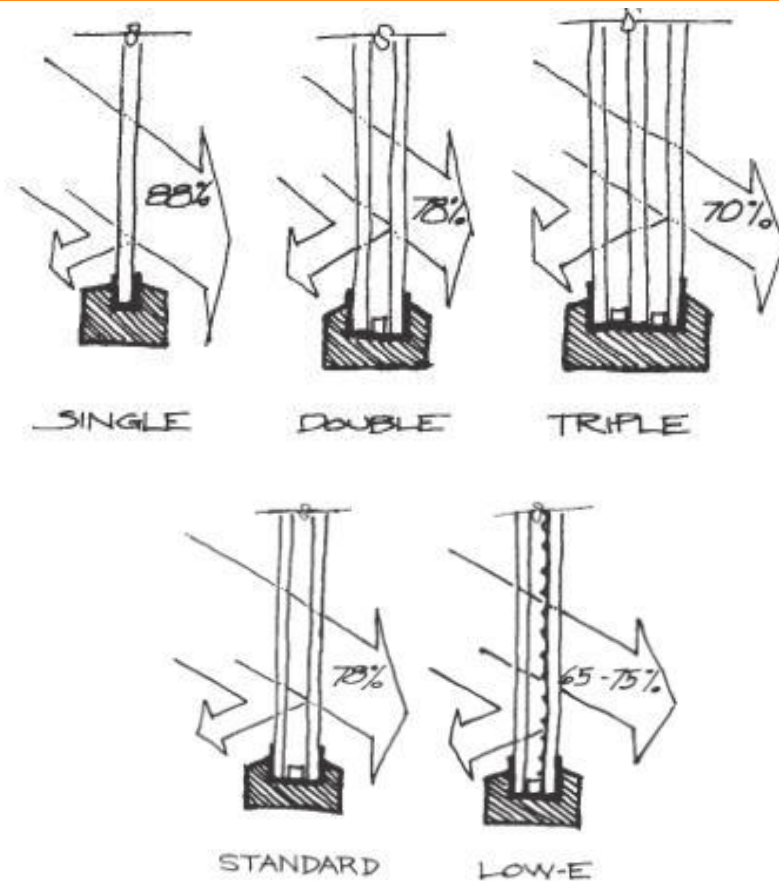
placement
and
orientation

How windows perform?



Window Design

http://www.uoxray.uoregon.edu/phys161/consumer_guide.pdf

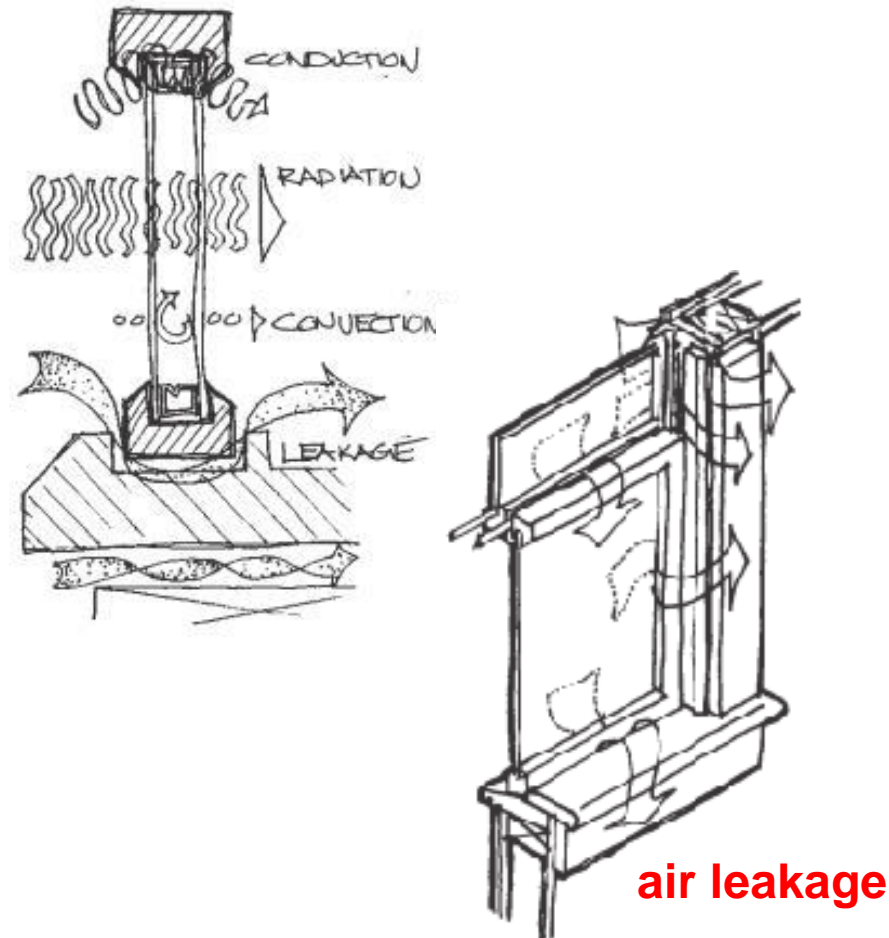


Glazing Choice

How windows perform?

Factors affecting heat losses

- The principal heat transfer processes in windows are:
 - radiation, conduction and convection
 - air leakage is responsible for a significant portion of heat loss.



How windows perform?

Balancing gains and losses

- there is a great deal of two-way “traffic” passing in both directions through windows.
- **South windows** often gain more solar energy during the day than they lose at night through convection, radiation and conduction losses.
- **North windows** are usually net losers of energy,
- **East and west** windows tend to be neutral during the heating season.
- **During the summer**, west windows may be net gainers of energy, posing an overheating problem.

- **High-performance window** technology is pointing the way to significant improvements in this balancing act between gains and losses — maximizing gains when needed, while at the same time minimizing heat transmission as never before.

External Doors

Door set which **separates the internal climate from the external climate** of a construction for which the main intended use is the passage of pedestrians, including the frame of the door which is defined as the component forming the perimeter of a door, enabling it to be fixed to the structure.



External Doors

- Exterior doors generally come in different varieties:
 - **Hinged, sliding or revolving doors**
- Exterior doors are generally made of metal, wood, or fiberglass over a foam core.
- Sliding door frames are usually made of metal or vinyl, and resemble a large horizontal sliding window
- A revolving door consists of three or four doors that hang on a central shaft and rotate around a vertical axis within a cylindrical enclosure.



Sliding door



Hinged door



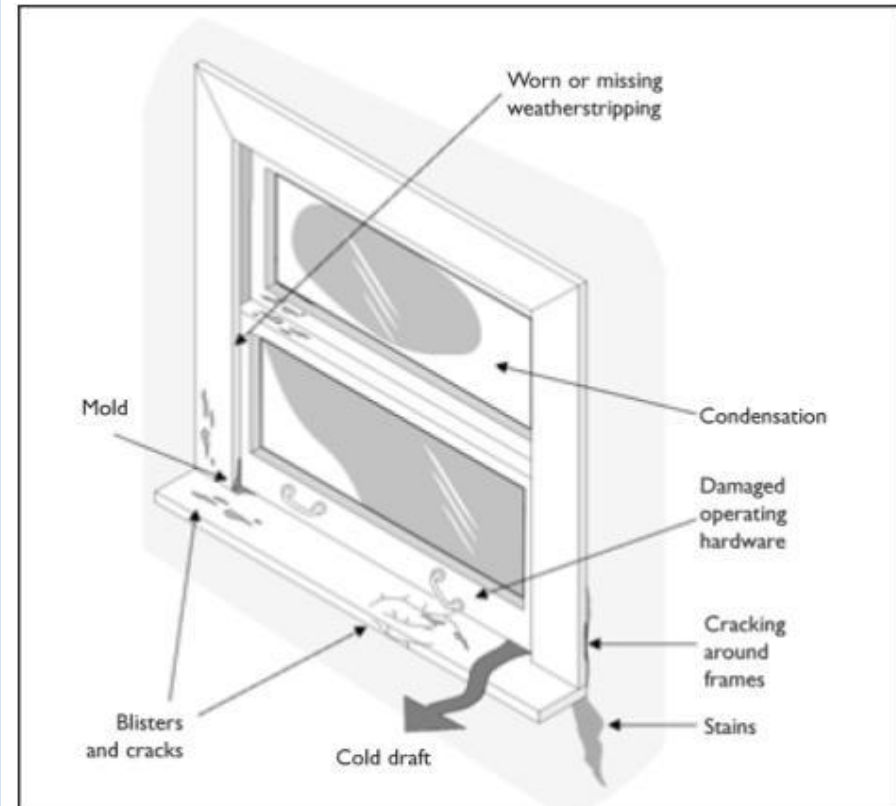
Revolving door

Windows and doors deterioration

Windows and exterior doors deterioration

Windows problems typically fall into three categories:

- Window unit
- Structural problems
- Water damage



http://www.supremewindows.net/pdf/cmhc_reno_windows.pdf

Windows and exterior doors deterioration

- Common window and door problems include:
 - Rot
 - Damage
 - Paint / stain
 - Caulking and flashing problems
 - Putty (glazing compound) problems
 - Sill slope
 - Deteriorated sills
 - Frame deformation
 - Cracked or broken glass
 - Condensation between pans



Windows and exterior doors deterioration

- Poor window performance may result in:

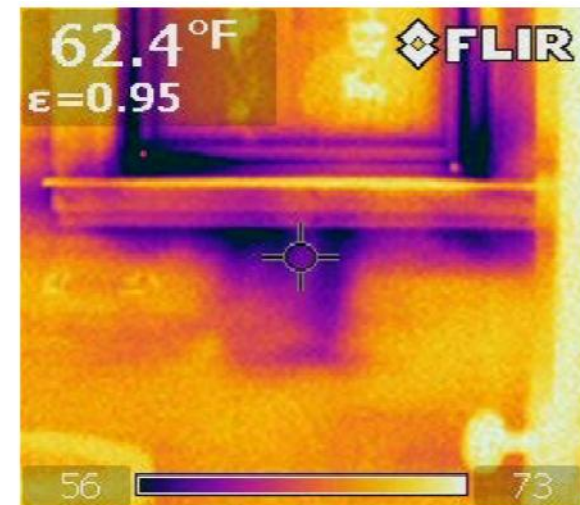
- Water leakage
- Air leakage
- Difficult operation
- High heating cost
- High maintenance and poor appearance

http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/measure_guide_wood_windows.pdf

56 °F = 13.3 °C

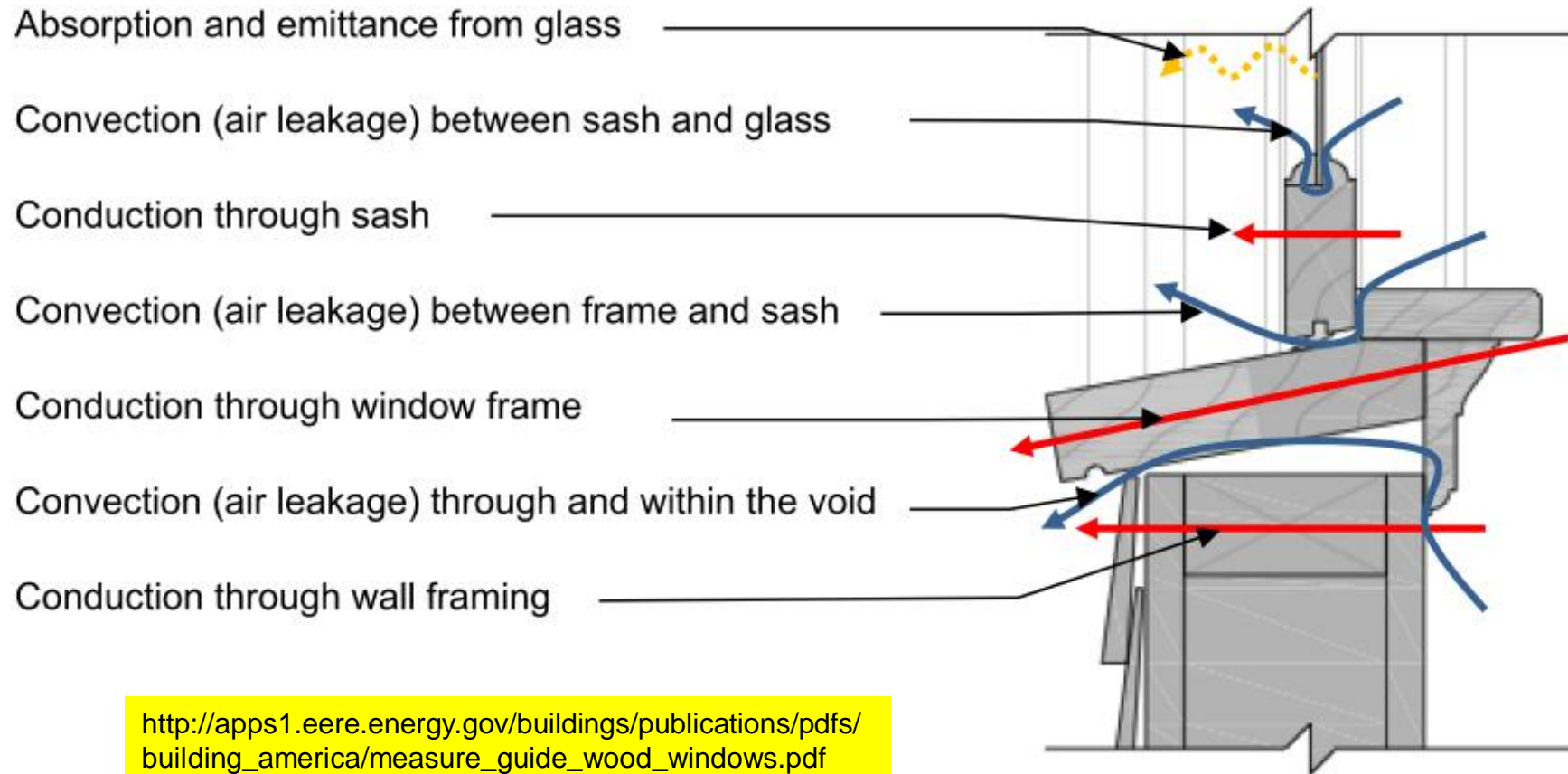
64 °F = 17.8 °C

72 °F = 22.2 °C



Infrared images of window air leakage at window interior apron trim. Dark colored areas indicate cold surface temperatures from cold outdoor air leaking into the building.

Windows and exterior doors deterioration



Windows and exterior doors deterioration

Water leaking as a result of small inclination of weather strip, and unworkable details (e.g. rip moulding)



Paint of a boarding of a garage door peels off strongly



The living room ceiling paint flakes off as a result of the structural and window frame leaks

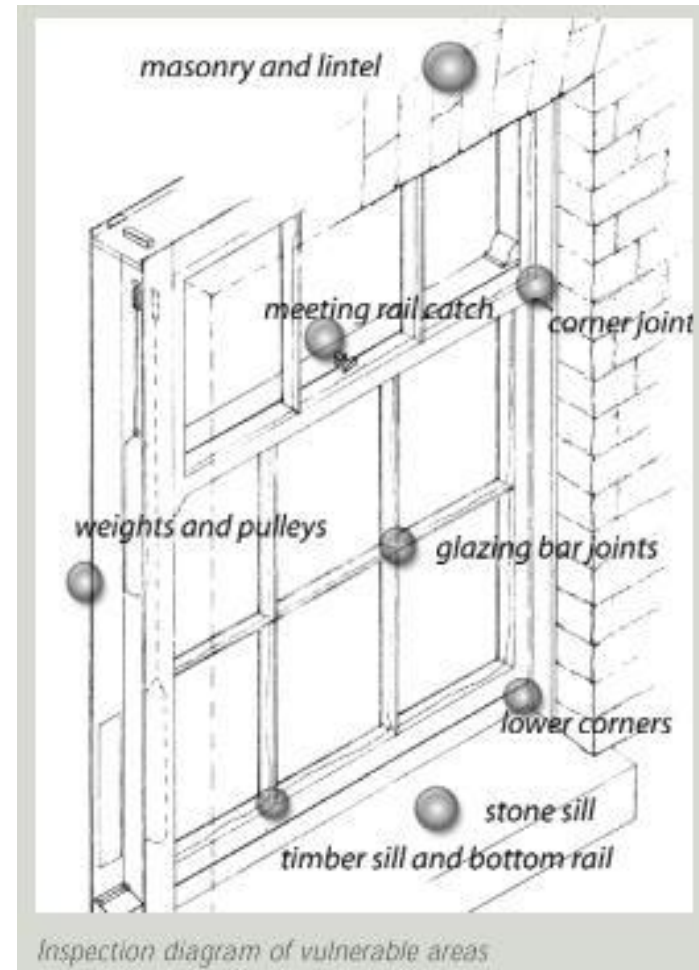
Windows deterioration: video



Windows and doors inspection

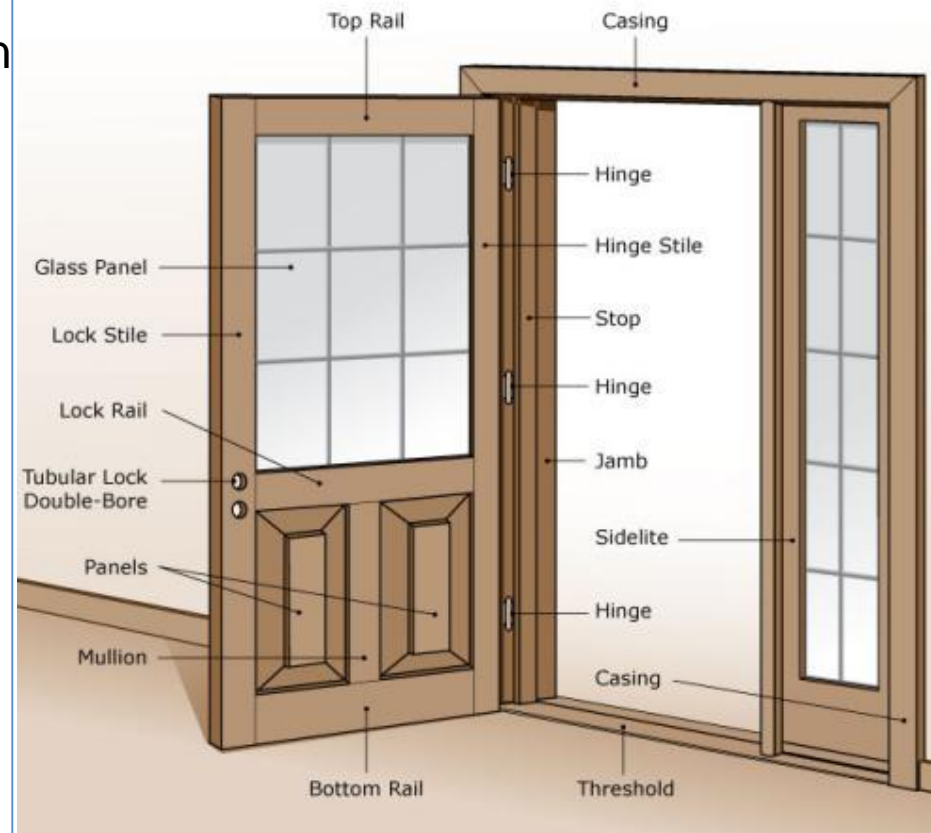
Windows and doors inspection

- **Exterior condition** of their frames, sills and sashes, and for overall operation and fit
- **Interior condition** and hardware of windows will be examined during the interior inspection.
- The **glazing compound** or putty around glass panels in older sashes should be examined especially carefully since this is often the most vulnerable part of the window and its repair is time consuming



Windows and doors inspection

- Exterior doors should be examined for their condition, overall operation and fit, and for the functionality of their hardware.
- Some buildings use glass framed doors of fixed and operable panels that have wood, vinyl-covered wood, and aluminum frames. Check the track of these sliding doors for dents, breaks, and straightness.
- Doors also should be inspected for the exterior condition of their frames and sills.



Window condition assessment

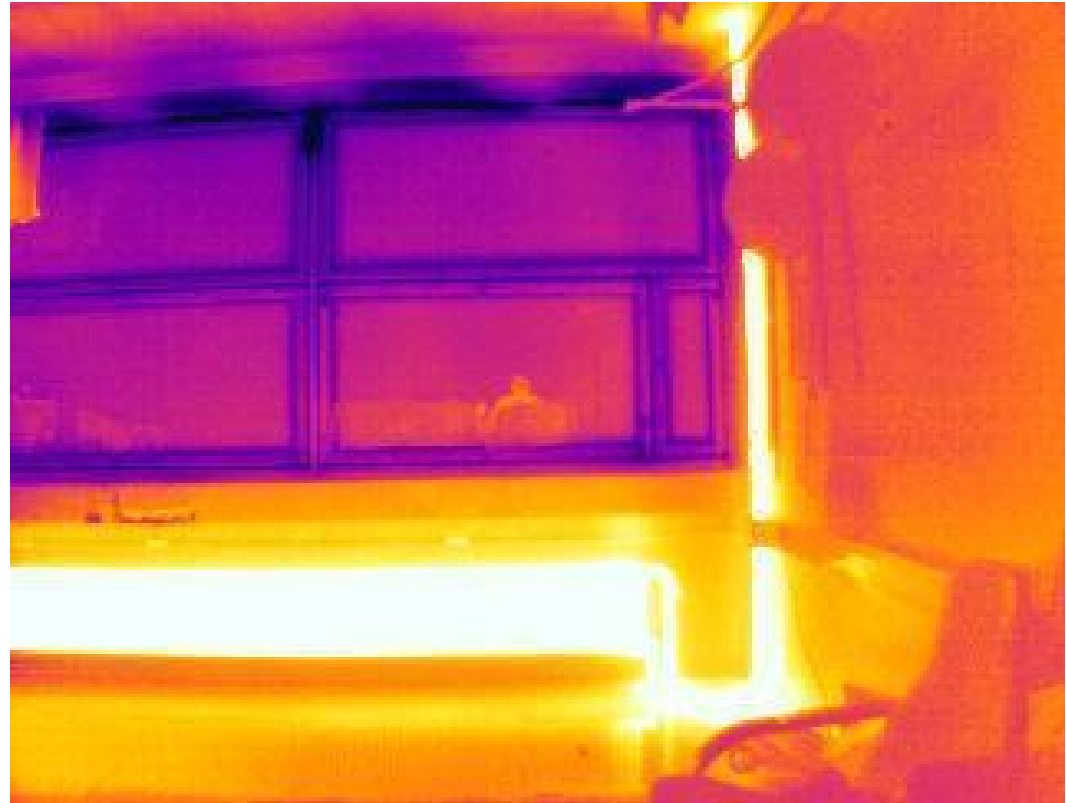
Checkpoints:

- Surface treatment of wooden parts
- The inner paint layer
- The outside paint layer
- Structural wood rot damage
- Puttying and moldings
- Fittings
- Water sill

Equipment:

- knife
- peak
- gauge
- smoke sign
- hygrometer (surface, wood moisture peak meter)
- surface temperature gauge
- thermographic camera

Window condition assessment: example

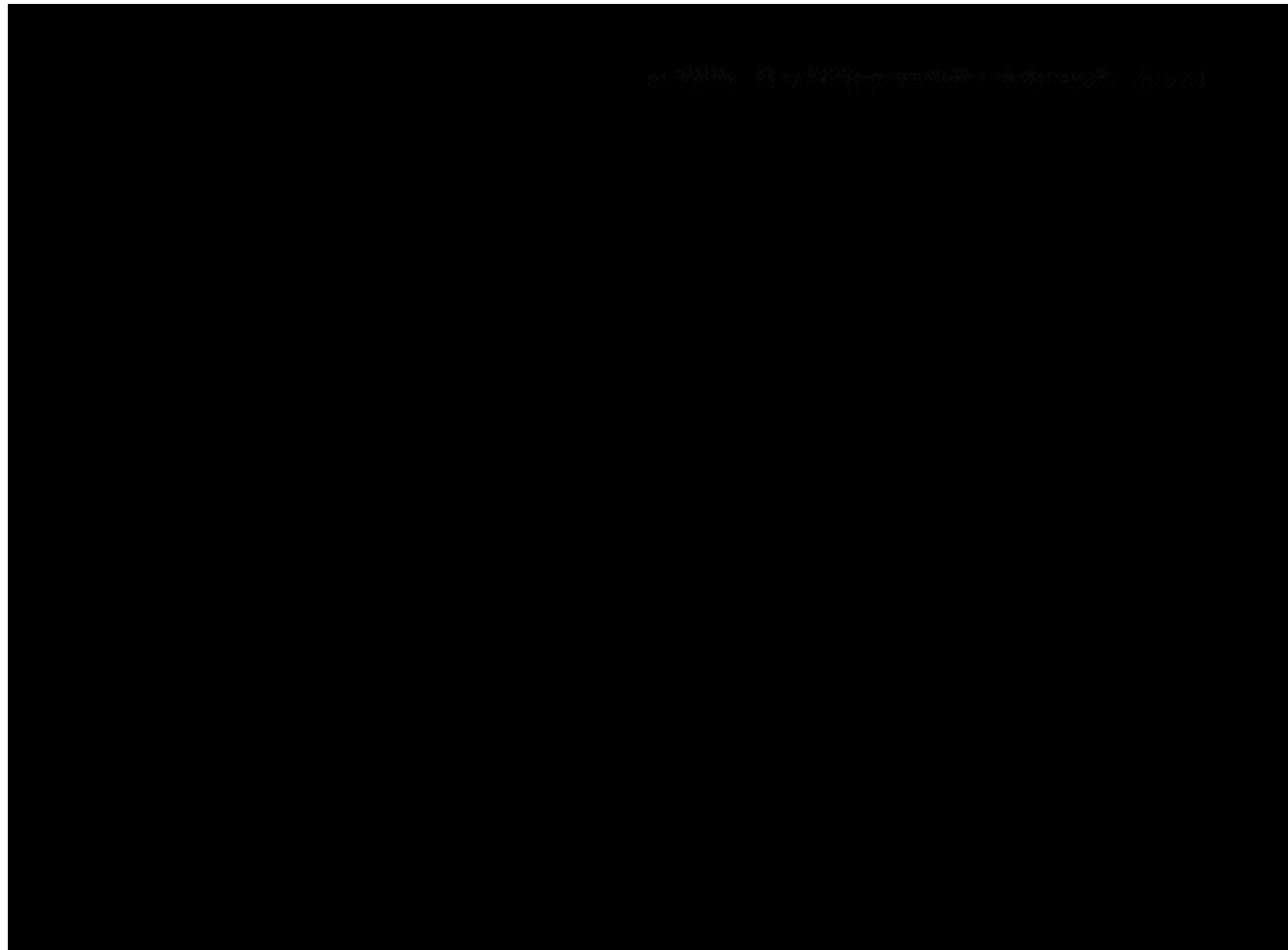


Colder areas visualized with a thermographic camera

Colder



Window condition assessment: Video



Windows and doors repair

Steps for window & door repair

STEP 1:

- Assess the extent of damage

STEP 2:

- Determine the most appropriate window and door repair strategy

STEP 3:

- Select replacement windows and doors

STEP 4:

- Properly apply flashing, caulking, and sealants

Window and door repair options

Only door lockset and/or hinge hardware is damaged:

- Replace door lockset and hinge hardware

Some window/door components are damaged, but frame and surrounding wall are undamaged

- Replace window glass, sash, track, and/or sill
- Install new secondary window (which includes thin retrofit frame) within existing window frame
- Install new door in existing door frame and weather strip
- Install new secondary door (which includes thin retrofit frame) within existing door frame

Window/door components and frame are damaged, but surrounding wall is undamaged

- Completely replace existing window assembly, including frame
- Completely replace existing door and frame with new pre-hung door

Window/door components, frame, and surrounding wall are damaged

- Rebuild/repair wall surrounding window/door so that opening is structurally sound, plumb, and square
- Completely replace existing window assembly, including frame
- Completely replace existing door and frame with new pre-hung door

Window maintenance repairs

- **Window partly replacement** can be done in the following ways:
 - Installing extra frame
 - Glass replacement with thermal glazing
 - Installing exchange frame
- **Window completely replaced** with a new window and inlet air vent to be improved ventilation performance.
- **Typical accessories include:**
 - Installation of air vents
 - installation of window blinds
 - Installation of insect screens



window blinds



Window air vent



insect screens

Energy-Efficient Windows and doors

Insulation value of windows (U-value)

- Simplified heat loss through any given surface is calculated using:

$$\text{Heat loss} = U * A * dT \quad [\text{Watt}]$$

U = Thermal transmittance [W/m²K]

A = Area of surface [m²]

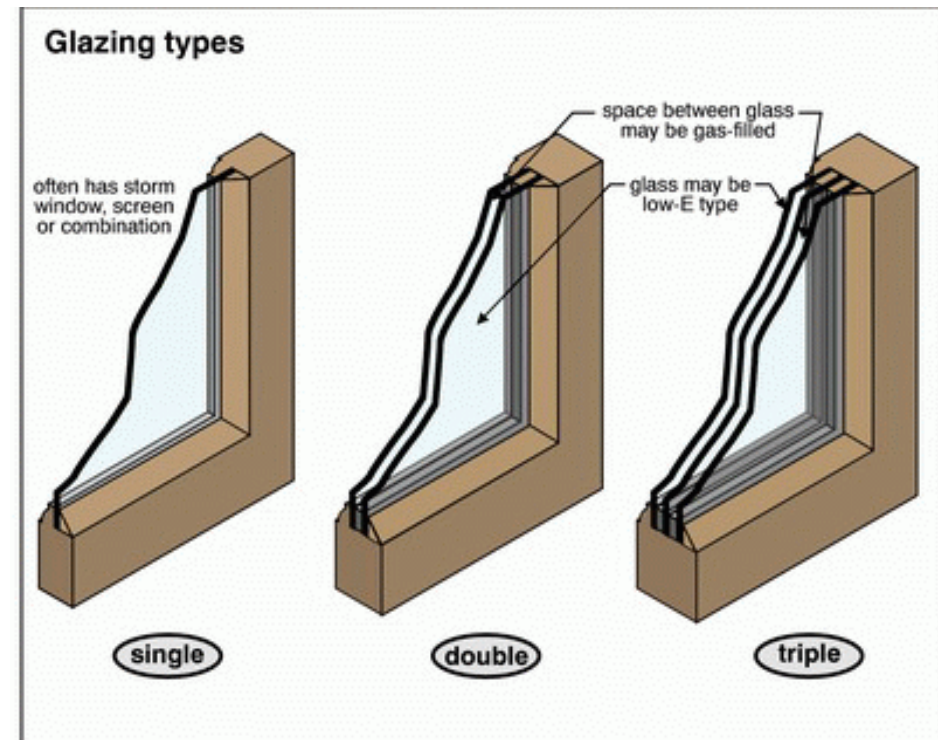
dT = Temperature difference
inside to outside [K]

- The formula Heat Loss = $\sum(U \times A \times dT)$
 - does include for thermal bridging in the main fabric elements of floors, walls and roofs.
 - does not include for thermal bridging around windows, doors, etc,

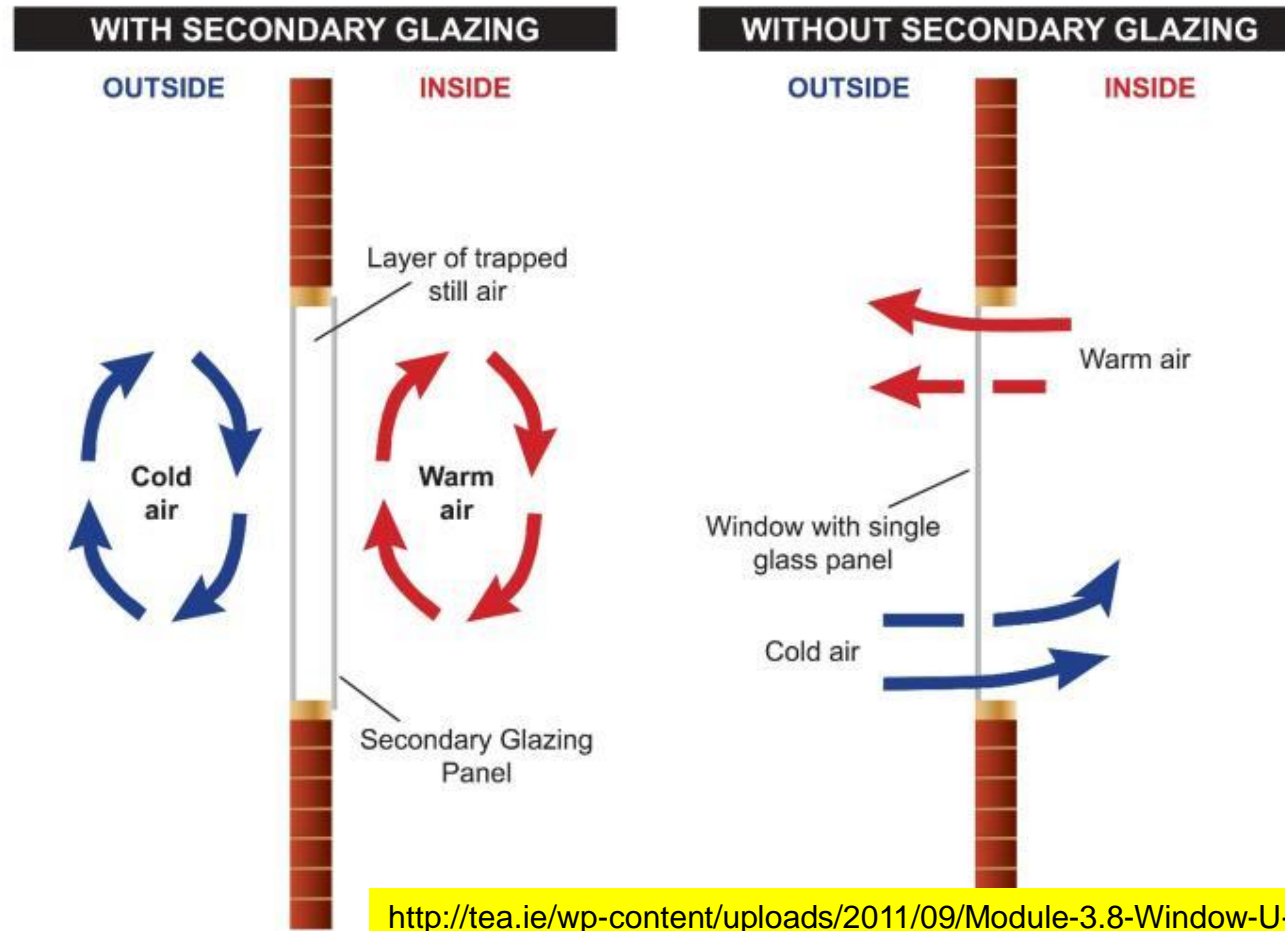
- EN ISO 10077-1 : Part 1: General
- The calculation of U-value is based on four component parts of the overall thermal transmittance:
 - a) elements containing glazing (windows)
 - b) elements containing opaque panels (doors)
 - c) the thermal transmittance of the frame
 - d) the linear thermal transmittance of the frame / glazing junction

Single or multiple glazing

- Options are single, double or triple glazing:
 - **Single glazing** – virtually obsolete apart from historical buildings
 - **Double glazing** – currently the most popular option in existing buildings.
 - **Triple glazing** – becoming more popular for new build buildings.



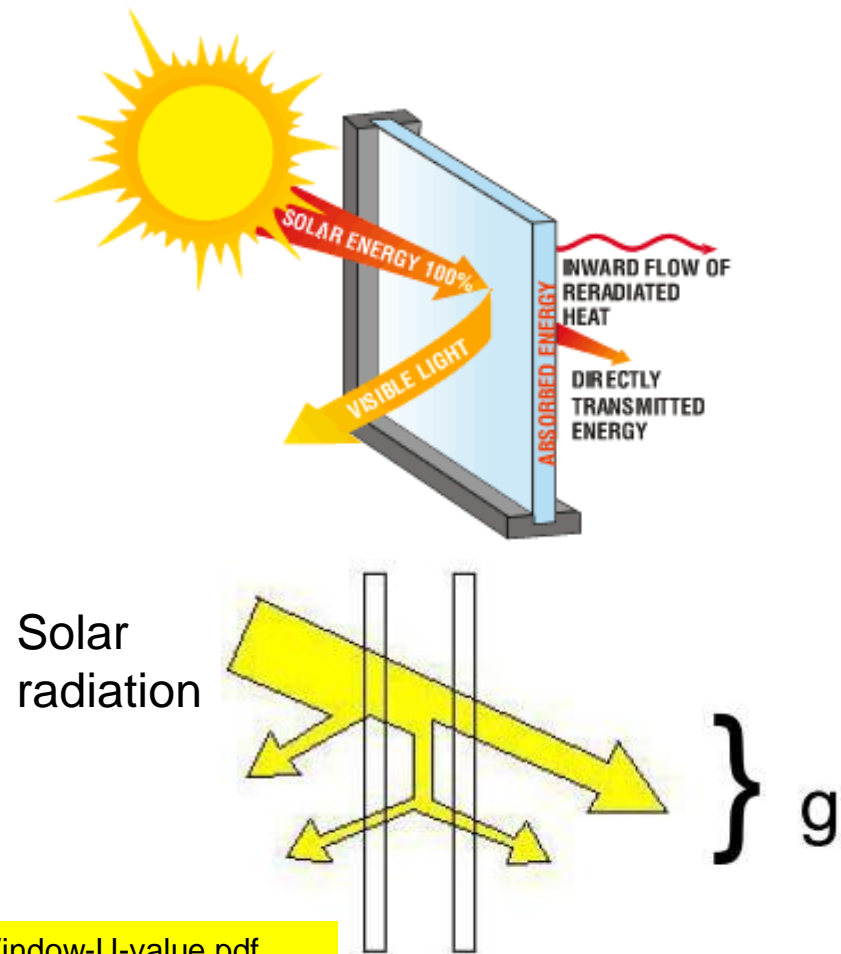
Single or multiple glazing



Single or multiple glazing

- **Solar factor g** = proportion of solar radiation transmitted + absorbed and emitted inwards
- Higher g value for low iron glass but expensive
- Air was the first gas used in the sealed cavity between the panes of glass.
- Argon is now the most widely used gas.
- Argon does not conduct heat as quickly as air, and so using argon reduces the U-value by approximately 10%.

<http://tea.ie/wp-content/uploads/2011/09/Module-3.8-Window-U-value.pdf>

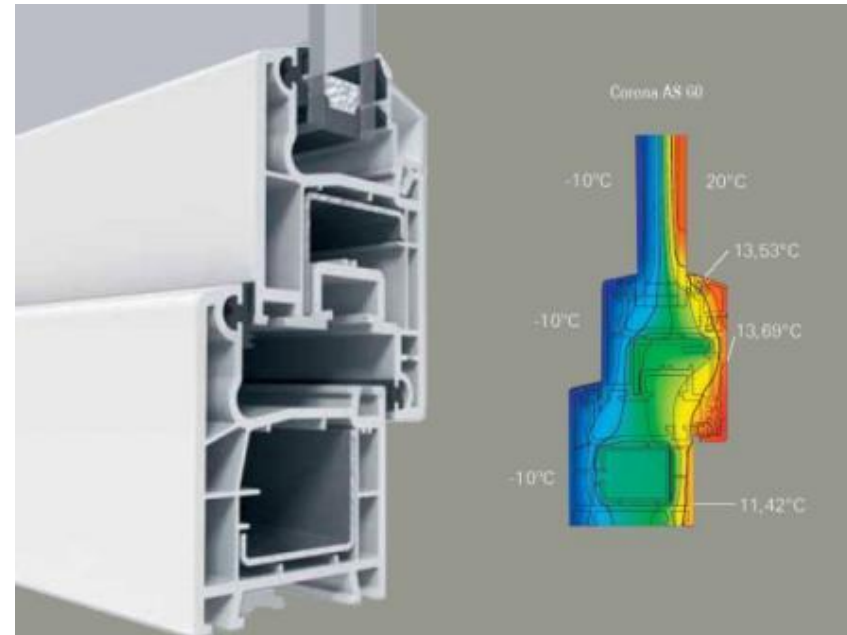


Impact on glazing U-value

Glazing type	U-value W/m ² K	Solar factor g in %
Double glazing		
12mm air gap no coating on glass	3.0	78
12mm air gap + low e hard coating	1.9	72
12mm air gap + low e soft coating	1.7	58
16mm argon gap + low e hard coating	1.5	72
16mm argon gap + low e soft coating	1.1	58
16mm argon gap + low iron glass + soft coating	1.1	75
Triple glazing		
12mm argon gap + low e hard coating 2 panes	0.9	42
12mm krypton gap + low e soft coating 2 panes	0.6	42
As above (krypton gap) + low iron glass	0.6	62

Window frames

- **uPVC frames** are most common since they come in a number of colors
- Hollow section frame with metal reinforcing.
- Need very little maintenance and have a long life.
- The material can be molded into strong hollow sections that provide insulating air cavities and reduce thermal bridging



U-Value

- uPVC 2 hollow chamber 2.2 W/m² K
- uPVC 3 hollow chamber 2.0 W/m² K

<http://tea.ie/wp-content/uploads/2011/09/Module-3.8-Window-U-value.pdf>

Window frames

- **Wooden frames** have a lower environmental impact but require annual maintenance
- Composite frames have an inner timber frame covered by an external uPVC or metal layer.
- **Aluminium or steel frames** are slim and long lasting and can be recycled.
 - frames are slim and long lasting and can be recycled
 - Metals have a high thermal conductivity and window frames must be made with a thermal break to avoid high heat loss

U-Value

- Wood (50mm hardwood) 2.4 W/m² K
- Wood (50mm softwood) 2.0 W/m² K



Wooden frames



Aluminium frames



Composite frames

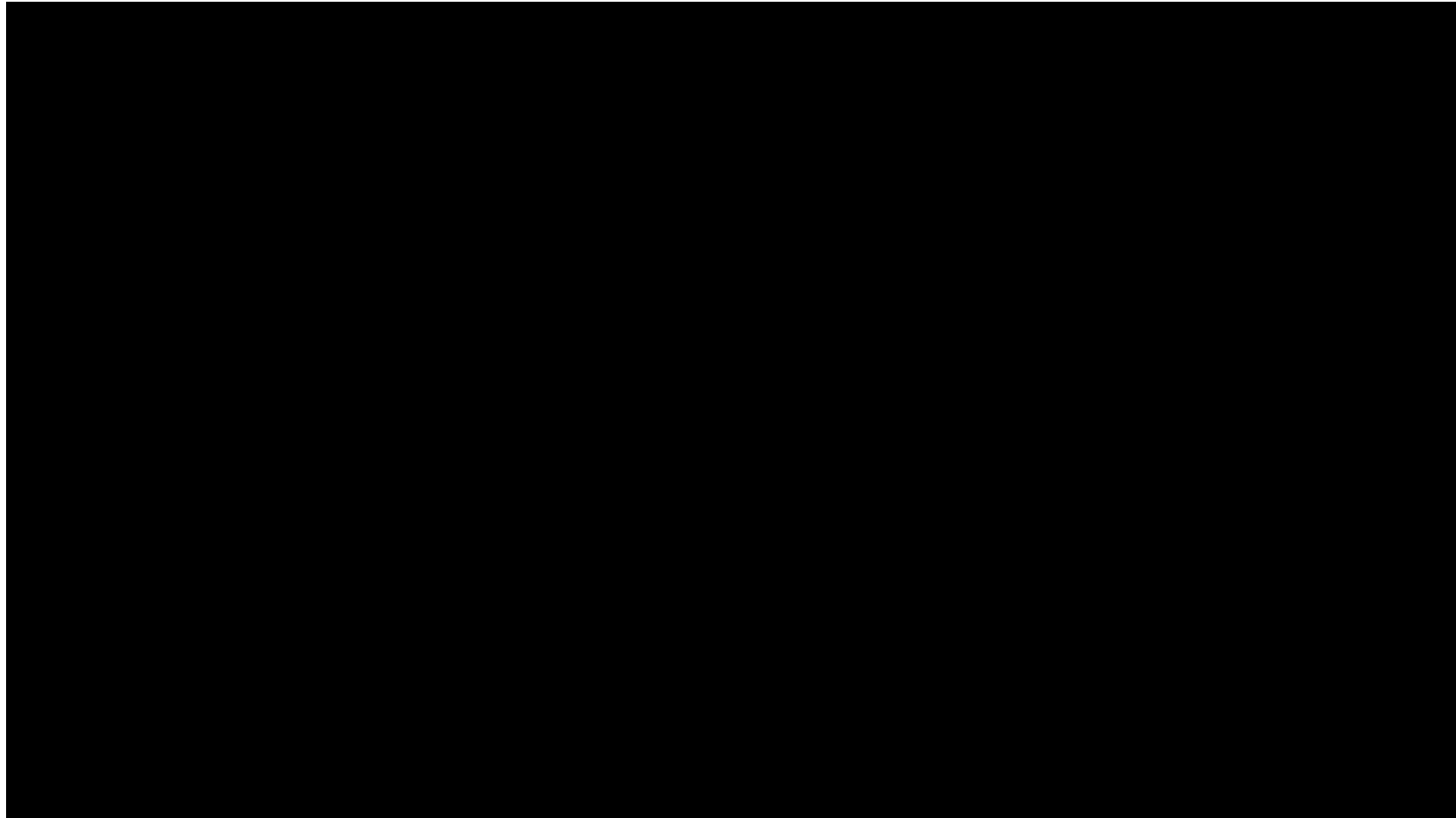
Window frames and glazing

- Typical default ratio of window frame to glazing area are as follows:
 - **uPVC**: 30% frame 70% glass.
 - **Wood**: 30% frame 70% glass.
 - **Metal**: 20% frame 80% glass.
- Since the U-value of glass is less than that of the frame, windows with larger frame area will typically have higher overall U-value and higher heat loss.
- When choosing glazing for a building the designer should take into account the heat balance of the glazing.

- The heat balance of the glazing will vary according to
 - the climate,
 - the solar exposure of the façade,
 - the characteristics of the building (particularly thermal mass),
 - and its use (and particularly the indoor temperature level).

<http://tea.ie/wp-content/uploads/2011/09/Module-3.8-Window-U-value.pdf>

Energy-Efficient windows and doors



Understanding energy ratings for windows and doors

1. U-Factor

- **Range: 0.20 to 1.20 [W/m²K]**
- The lower the number, the better an insulator the window or door is.
- Climate recommendations:
 - Northern: 0.35 or less
 - North Central or South Central: 0.4 or less
 - Southern: 0.60 or less
- A low U-factor means that less heat escapes in the winter, which makes it particularly important in cold northern climates

2. Solar Heat Gain Coefficient (SHGC)

- **Range: 0 to 1 [0 to 100%]**
- The lower the number, the less solar radiation — and heat — the window or door allows inside.
- Climate recommendations:
 - Northern: The highest you can find (paired with a low U-factor) if cooling isn't a significant concern; up to 0.55 if cooling is a significant concern.
 - North Central: 0.4 or less for climates with significant air conditioning; up to 0.55 for climates with moderate air conditioning.
 - South Central or Southern: 0.4 or less.
- SHGC refers to the solar radiation a window or door allows inside.

Understanding energy ratings for windows and doors

3. Visible Transmittance

- **Range: 0 to 1 [0 to 100%]**
- Lower number means the room will be dimmer; a higher number means the room will be brighter.
- This number applies to windows or doors with windows only.
- Visible transmittance is the amount of light a window allows to pass through.
- With older window glazing techniques, VT and solar heat gain were basically the same; the brighter a room, the hotter it got.
- But new technologies allow windows to let in lots of light while the room stays cool.

4. Air Leakage

- **Range: N/A, but .0.3 is standard building code [m^3/min or $\text{m}^2/\text{window/door area}$].**
- The lower the number, the more airtight the window or door.
- Air Leakage represents the amount of air that the window or door's frame allows to pass through.

Understanding energy ratings for windows and doors

5. Condensation Resistance

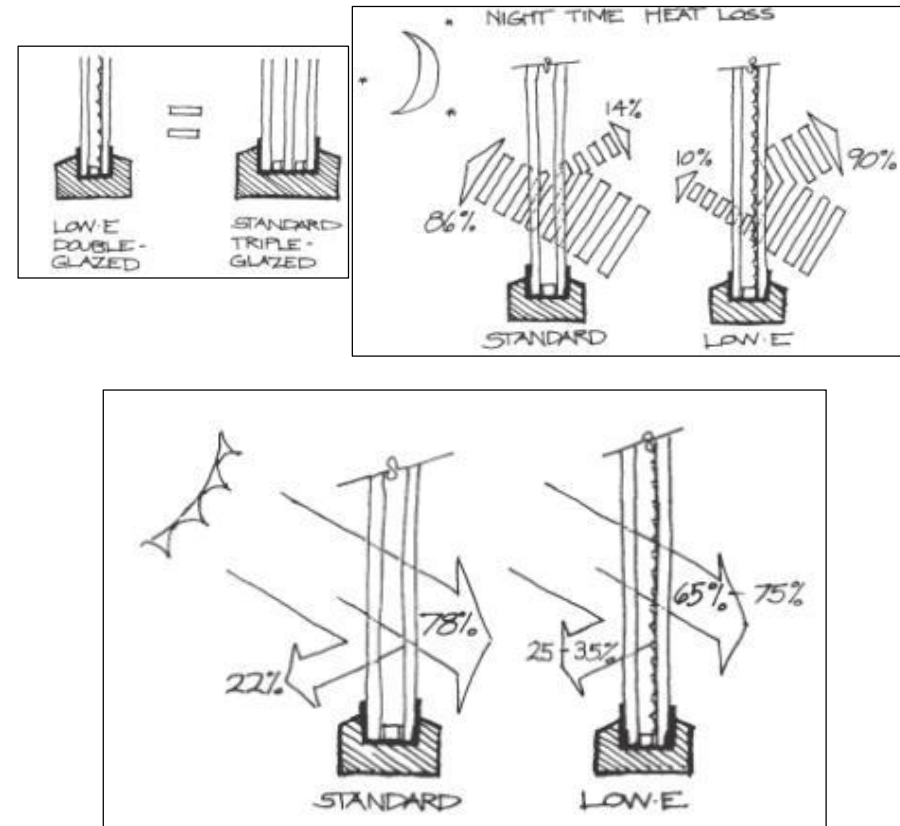
- **Range: 1 to 100**
- The lower the number, the more condensation the window or door allows to build up.
- Condensation resistance is a measure of how much moisture a window or door allows to build up on the surface (which can drip onto wood and cause mold or discoloration) or between glazing layers (which can't be clean and blocks your view).

High-Performance Windows

High-Performance Windows

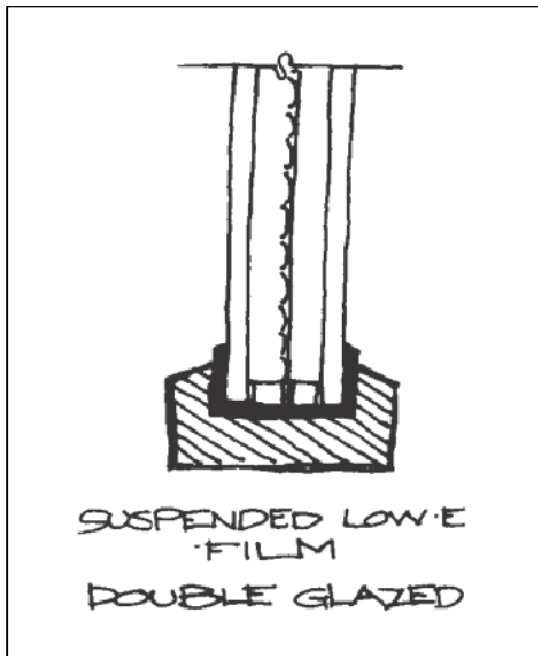
- High-performance window is several times better than the windows of just a few years ago
- The list of high-performance window improvements currently available:
 - low-E coatings,
 - inert gas fills and
 - insulated frame and edge components

low-E coatings

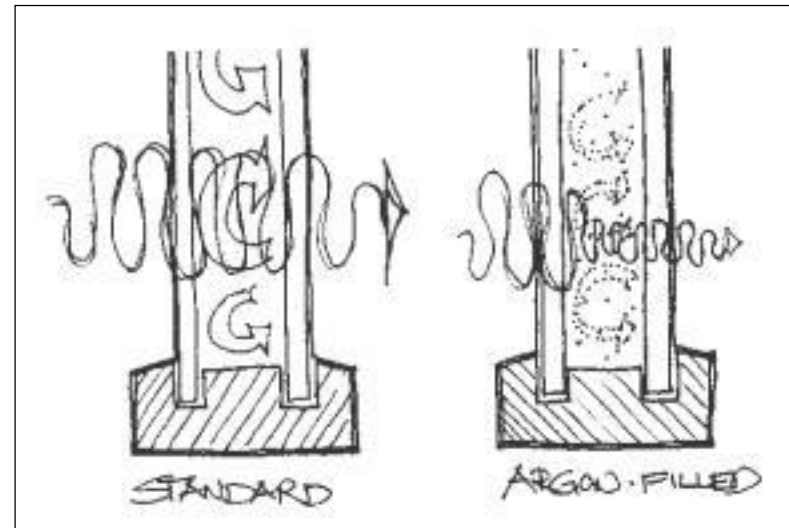


High-Performance Windows

Special Films



Gas Fills



Summary

Lecture summary

- Introduction
- Windows and doors deterioration
- Windows and doors inspection
- Windows and doors repairing
- Energy-Efficient Windows and doors
- High-Performance Windows

Next Lecture:

- 14.03.2016
- Strengthening of building structures