Expert Series:

Understanding Condensation on Glass

GUARDIAN® GLASS

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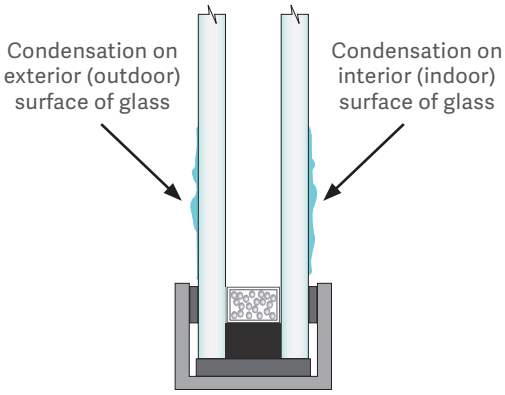
Glass Condensation Overview

Occasionally, moisture may condense on the outdoor or indoor surfaces of insulating glass units (IGUs). Condensation does not indicate a problem with the glass itself but simply results from a combination of atmospheric and/or environmental (climatic) conditions that allow the formation of water to accumulate on the surface of the glass.

In most cases, condensation is a temporary condition and does not affect the quality or integrity of the IGU.



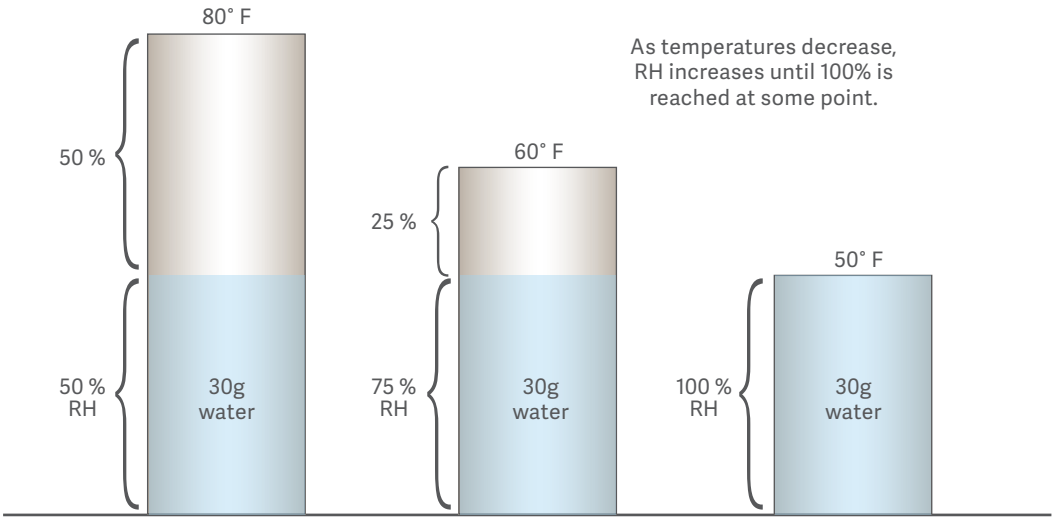
Insulating Glass Unit

Important Terms and Definitions for Glass Condensation

Absolute Humidity – The amount of water vapor in air regardless of air temperature.

Relative Humidity (RH) – The measure of water vapor in air (at a specific temperature) compared to the maximum amount of water vapor the air is capable of holding at that temperature. The warmer the air, the more moisture that can be held by the air; conversely, the cooler the air, the less moisture can be held.

The figure below illustrates the relationship between temperature and relative humidity.



Proportion of water vapor (Relative Humidity) to air mass at different temperatures

A relative humidity of 100 percent indicates that the air is holding all the water it can at the current temperature and any additional moisture (or reduction in air temperature) at that point will result in condensation. For example, a relative humidity of 50% means the air is holding half the amount of moisture that it could potentially hold. As the temperature decreases, the amount of moisture in the air doesn't change, but the relative humidity goes up (since the maximum amount of moisture that cooler air can hold decreases).

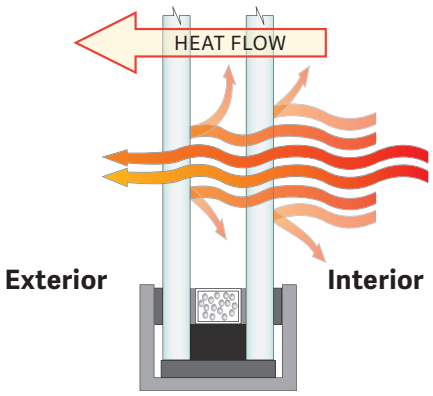
Dew Point – The temperature at which a mass (volume) of air must be cooled for water vapor to condense into a liquid form.

Condensation – The conversion of water from a gaseous (vapor) form to a liquid form. Condensation occurs primarily when vaporized moisture comes into contact with a cold surface where the temperature of the surface is at or below the dew point.

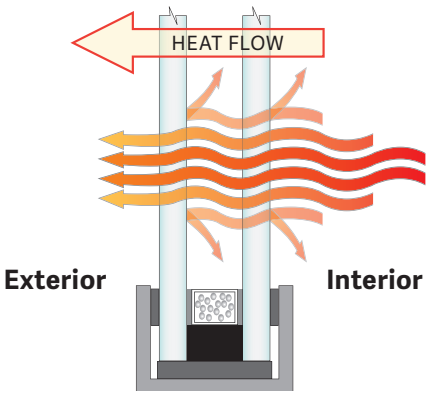
Emissivity – The relative ability of a surface to emit energy in the infrared (IR) spectrum by the process of radiation.

U-Value – A measure of the rate of non-solar heat loss or gain through a material or assembly. U-value indicates how well a material allows heat to pass through it. U-values generally range between 0.20 and 1.20. The lower the U-value, the greater a material's resistance to heat flow and the better its insulating value.

U-values are often referenced for energy efficiency of windows and doors. In the case of a window, the U-value may be expressed for the glass alone (known as center-of-glass) or the entire window, which includes the effect of the frame and the insulating glass unit spacer materials.



Low U-Value
Reduced heat transfer through glass unit.



High U-Value
Increased heat transfer through glass unit.

Outdoor Condensation Overview

Condensation on the outdoor glass surface of an IGU will occur whenever the surface temperature of the glass is at or below the dew point, which can vary depending on outside air temperature and relative humidity. In addition to climate, other variables that can affect condensation include:

- Cloud coverage
- Time of day
- Air movement
- Architectural orientations and building features
- Vegetation/Landscaping
- Time of year
- Efficiency of window/glazing unit

Instances of outdoor condensation are generally a temporary effect. Upon any one of the climatic variables changing, the condensation on the glazing will usually dissipate within a short period of time in much the same way as morning dew. Where insulating glass windows are concerned, the presence of condensation is typically an indication that the windows are doing what they are designed to do; that is, block the heat from inside from reaching the outside. The result is the outside lite of glass in the IGU becomes cooler, lowering the dew point so that condensation temporarily appears. This often happens in the morning.

During the day, glass temperatures will increase causing outdoor condensation to evaporate when either the heat loss to the sky is blocked by clouds, the wind increases, or sunlight is absorbed

by the glass. Architectural features including roof overhangs, exterior shading devices or other structures can also block sunlight and increase condensation. At night, the exterior surface of the glass can radiate heat into the night sky causing the temperature of the glass to decrease below the dew point of the ambient air. Once this occurs, moisture from the air will condense on the surface of the glass and water will form. As the glass temperature increases above the dew point throughout the day, the condensation will evaporate into the air.

Influences of Landscaping

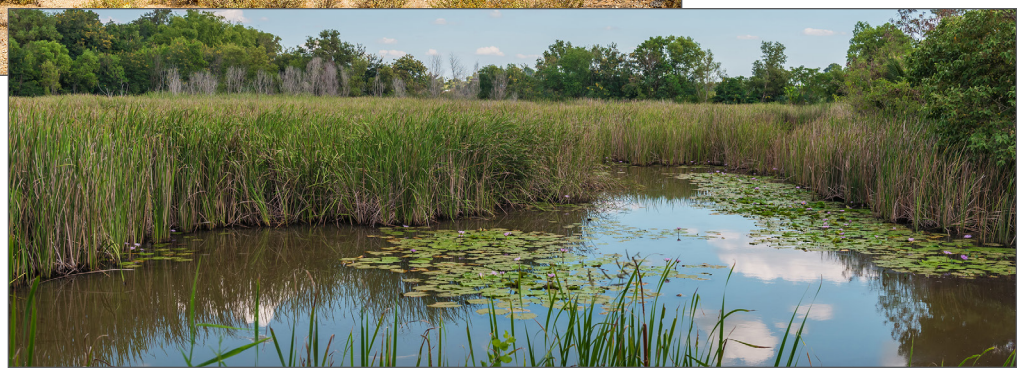
Ponds, creeks, pools, water faucets, lawn sprinklers, etc. which are located near window units can increase humidity near the glass. Shrubs, trees, hills (terrain), or other surrounding landscapes can block sunlight or reflect solar radiation, all of which can affect how and when condensation occurs.

Seasonal/Geographic Factors

Seasonal and geographical factors will also affect when and/or how often condensation will occur. Dew point and relative humidity combinations will vary throughout the year. Each new season will bring different climates that will affect outdoor condensation. During the spring and fall, when cool nights follow warm, humid days, moist air that is in contact with the outer glass of high performance low-E IGUs will likely condense on the glass.

Temperatures and humidity vary greatly depending on geographic location. In the southeast U.S. summer dew point temperatures range from about 65˚F to 75˚F. When temperatures inside the building are within this range, interior condensation on glass can occur.

In the midwest, drier climates tend to reduce occurrences of condensation. In northern or arctic regions (Alaska, Northern Canada) seasonal variations of temperatures and humidity vary tremendously causing far greater differences between indoor and outdoor temperatures. In hot humid wetlands, relative humidity can approach 100% as the norm, and condensation will be more likely at higher temperatures.



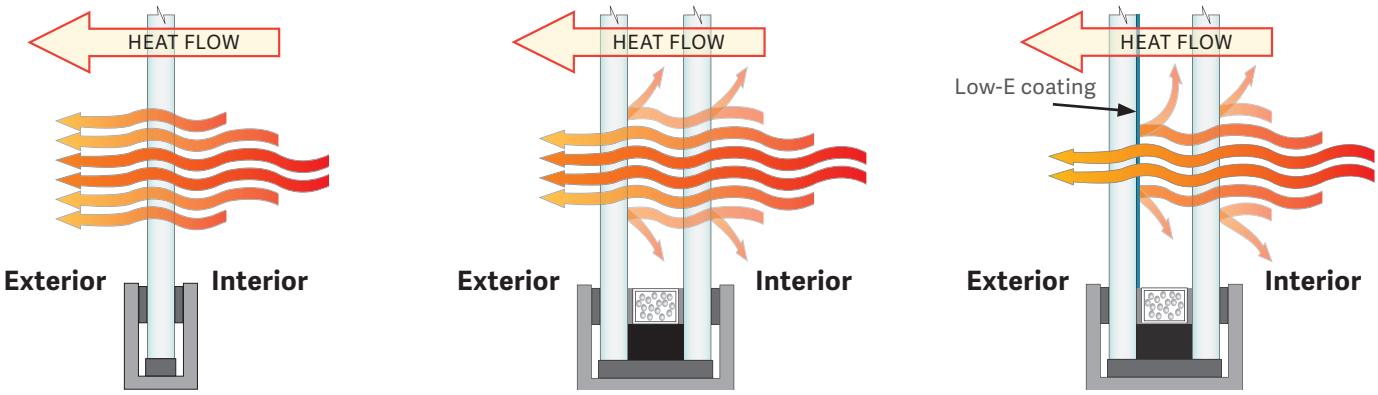
Monolithic Glass vs. Double Pane IGU

Condensation is rarely found on the exterior surface of a single pane window. This is because a single pane of glass has poor thermal insulation (high U-value) and allows a significant amount of heat to escape from inside a warm room to the outside environment. Therefore, the outside surface temperature of a single pane window is usually higher than the dew point temperature.

With a double pane IGU thermal insulation improves, but heat can still escape through the glass and keep the exterior glass surface warm, thereby preventing outdoor condensation to form in most circumstances.

Low-E Glass

Today's higher performing low-E coatings are almost always used on the outboard lite of an IGU to improve thermal performance. Low-E glass reduces heat loss through the glass from the warmer interior to the outside glass surface. Heat loss can be reduced by as much as 50% with a Low-E coating. Because the Low-E coating reflects heat back inside (see figure below), the outside surface of the glass stays cooler and condensation can occur on the exterior glass when atmospheric conditions are right, and the surface temperature is lower than the dew point. This indicates the low-E IGU is working as intended and retaining heat in the house or building.



Single Glazing
Heat flows through to the exterior surface.

Conventional Double Glazing
Heat flow reduced but still warms exterior glass.

Low-E Insulating Glass Unit
Heat flow restricted, keeps outer glass cool.

Interior Surface Low-E Coatings

Interior-surface coatings can be used in combination with Low-E coatings in double and triple IGUs to provide an enhanced thermal barrier and improve energy performance. High-performance IGUs with Low-E and interior-surface coatings are exceptionally good at preventing heat transmission through the window, ultimately causing the outdoor glass temperature to be slightly cooler than low-E IGUs without the interior coating. The heat that would be absorbed by an IGU without an interior-surface coating is instead reflected back inside, resulting in a warmer room, and a cooler interior glass surface. The cooler interior glass surface may result in condensation occurring on the glass sooner than it would without the interior surface coating.

Window Frames

The sash and frame of a window represent 10% to 30% of a window's total area, depending on the window size and design. The material used to manufacture the frame can significantly impact heat loss and related condensation resistance. In colder climates, in non-residential buildings, where aluminum frames are used, thermal breaks should be specified in order to minimize heat transfer and condensation on the frames. In colder climates, with residential buildings, most products use wood, vinyl, or other non-metallic frames. Some door frames will also conduct heat readily. For solid doors, insulating metal or fiberglass doors are usually the best choice.

Condensation in Commercial Applications

In commercial applications, nighttime condensation on the exterior glass surface is not often an issue of importance because it quickly dissipates as the day progresses and the glass temperatures increase. If the condensation must be removed quickly, the HVAC vents could be adjusted to direct warm air toward the window to balance the building air temperature with the exterior dew point temperature.

Nighttime condensation can also be prevented by shielding the windows from direct line-of-sight radiant heat transfer with the sky through appropriately placed trees or awnings.

In very hot and humid conditions, exterior surface condensation may be seen with air conditioned, single-glazed, lobby areas of commercial structures when the temperature of the monolithic clear or tinted glass falls below the exterior dew point temperature. In this case, the opposite treatment is needed to prevent condensation: HVAC ducts should not blow cold air at the glass but rather should be directed away from the glass, allowing the warmer exterior air to heat the glass to a temperature above the dew point of the outside air.

Outdoor Condensation

While the climate cannot be controlled (relative humidity and/or dew point temperatures), a possible step to take to reduce exterior condensation is to warm the inside surface of the window which to some extent will also warm the outside glass surface. Raising the thermostat setting may be the only option to do this. Exterior shutters, shades or even trees can help reduce summer condensation on exterior glass panes.

The presence of condensation on window units on days where temperature and humidity are right for condensation to occur is a reassurance that your windows are doing their job which is to prevent heat from escaping the home or building.

Indoor Condensation

Although the same principles of condensation apply to indoors as well as outdoors, there are some additional factors to consider. During winter, when windows are typically kept closed, and there is a reduction in the rate of air exchange, there is often an increase in interior humidity levels.

People and pets produce moisture when they breathe or perspire. Even indoor plants produce moisture. Water vapor is added to indoor air through everyday household activities such as cooking, showering, bathing and laundry. Higher humidity will often occur during the colder months when windows are closed, and indoor air circulation is reduced.

Humidity Levels

To maintain proper humidity levels and avoid indoor condensation during winter, the Fenestration Glazing Industry Association (FGIA) recommends a maximum percentage of indoor relative humidity based upon varying outdoor air temperatures with an indoor air temperature of 70°F/20°C as indicated in Table 1.

Table 1

Recommended Indoor Relative Humidity		
Outdoor Air Temperature °F	Outdoor Air Temperature °C	Indoor Relative Humidity (%RH)
20° to 40° F	-7° to 4° C	≤ 40%
10° to 20° F	-12° to -7° C	≤ 35%
0° to 10° F	-18° to -12° C	≤ 30%
-10° to 0° F	-23° to -18° C	≤ 25%
-20° to -10° F	-29° to -23° C	≤ 20%
Below -20° F	Below -29° C	≤ 15%

This table should be used a guide only. Acceptable or comfortable humidity levels will vary from season to season, from house to house, and even between rooms in the same house. Humidity levels can be measured by the use of a tool called a hygrometer that measures relative humidity.

How Windows Can Help

Higher performing windows can improve thermal performance and increase condensation resistance. Some ways to improve window performance include using double or triple pane IGUs, Low-E coatings, low-conductance gas fills such as argon or krypton, and the use of warm edge spacers, which are placed between the glass lites. These strategies allow the humidity inside the room to be higher than a room with ordinary single pane glazing before condensation occurs.

The first step of controlling humidity begins with installing new energy-efficient windows with a high-performance rating. High efficiency windows may not solve all condensation concerns, but properly installed, sealed and insulating windows are the first step towards eliminating condensation issues.

Further reducing humidity in homes will also help by opening doors and windows on a periodic basis to exchange air in the house. Exhaust fans in bathrooms and kitchens and sealing the house with weather stripping and caulking will also help. Humidifiers can be sources of excessive moisture so they should not be overused.

Tips to reduce indoor humidity and interior window condensation:

There are various control measures that can be applied to minimize or eliminate condensation from occurring.

- Install an air exchange unit or a humidity control device to maintain the proper level of humidity
- Use proper vapor barriers and adequate drainage to reduce the amount of external moisture
- Ensure cold air from registers does not flow directly on to the interior surface of the glass
- Turn furnaces with humidifiers off until condensation reduces
- Ensure the exhaust from the clothes dryer is vented outside
- Ensure gutters drain water away from the house
- Avoid drying firewood in the house
- Waterproof damp basement walls and floors
- Use exhaust fans while cooking
- Open a window when doing laundry
- Close the bathroom door and open a window after baths and showers
- Ventilate the home at least once a day

Learn More About Condensation on Glass

If you need more information, Guardian's Technical Services group is available to assist with the evaluation of condensation on glass. Please contact Guardian at https://www.guardianglass.com/us/en/contact or call 855-58-GLASS (45277).

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