Condensation on Indoor Glass Surface

The minimization of condensation on the indoor glass surface is an important consideration in the selection of windows for residential applications as well as in glass and metal framing systems for commercial applications. With knowledge of the factors that influence the formation of condensation and the selection of appropriate products combined with good design principles, the desired results can be achieved.

The purpose of this document is to provide a simplified explanation of condensation, what causes it, and to offer a relative indication of the performance of select Vitro glass products regarding the likely occurrence of condensation.

An in-depth discussion of the psychrometric principles involved is beyond the scope of this document. The reader is encouraged to review reference resources such as the 2021 *ASHRAE Handbook—Fundamentals* or other textbooks dealing with psychrometrics to gain the necessary level of understanding.

When the temperature of any object (e.g., metal, wood, cement, glass, plants, etc.) falls below the dew point temperature of the surrounding air, condensation from the water vapor in the surrounding atmosphere begins to form on the surface. NFRC 500-2017: "*Procedure for Determining Fenestration Product Condensation Resistance Values"* defines the dew point temperature as: *temperature at which water vapor condenses to liquid water at a given relative humidity.*

Obviously, the goal for windows and commercial glazing systems is to select products that under the specified ambient design conditions have thermal properties that maintain the indoor surface temperature above the dew point temperature thereby preventing condensation.

There are currently four condensation ratings:

- NFRC's Condensation Index (CI): ANSI/NFRC 500-2023
- NFRC's Condensation Resistance (CR): NFRC 500-2017
- FGIA's Condensation Resistance Factor (CRF): AAMA 1503-09
- CSA's Temperature Index (I): A440.2-14 & A440.3-14

These different methodologies evaluate condensation; however, each uses the same standardized environmental conditions [exterior: -18ºC (0ºF) and interior: 21ºC (70ºF)] and provide dimensionless ratings between 1 and 100, with the higher values indicating better performance.

To assist design professionals and glazing specifiers to make proper choices, the American Architectural Manufacturer Association (AAMA which is now merged with IGMA under FGIA) developed the "*Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors and Glazed Wall Sections"*. The current version is available from FGIA as Publication AAMA 1503-09. More recently, the National Fenestration Rating Council published ANSI/NFRC 500-2023: *Procedure for Determining Fenestration Product Condensation Index Ratings* and also NFRC 501-2020: *User Guide to the Procedure for Determining Fenestration Product Condensation Index Rating.* This guide provides assistance to determine the CI range for consideration due to

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environmental factors that lead to the possible formation of condensation.

The AAMA 1503 test method measures the thermal characteristics of the glazing (i.e., windows, doors, glazed exterior wall sections) under steady-state conditions using a specified set of design conditions.

The NFRC 500 procedure includes both a test method and a computer simulation method. The test method is similar but not exactly the same as for AAMA 1503. The simulation method is based on a two-dimensional heat transfer simulation and must be performed with NFRC approved software tools.

Whether by test or simulation, the purpose is to establish a temperature profile under the specified design conditions across the indoor surface of both the glass and framing system. Finally, using calculation techniques given in the referenced documents, the condensation rating is calculated.

> It is important to recognize that a meaningful rating number is based on not one but several measured or simulated temperatures at various locations on both the glass and framing system.

The procedure for selecting the required locations for collecting data is detailed in the referenced AAMA and NFRC documents.

Glass or any other object will have temperature variations and will be colder at the bottom than at the top since cold air falls and hot air rises. In addition, glass installed in framing systems typically can have significant temperature variations across the surface. These variations are influenced by the framing system design and the surrounding air movements. In the case of insulating glass units, the spacer material and design, sealant material and dimensions, and changes in barometric pressure (which causes the air space gap to expand or contract) can affect temperature variation. Therefore, a condensation rating for the glass itself is meaningful only when generated for a specific framing system and only for the specified design conditions used to perform the test or simulation.

Condensation may occur even after rigorous attention is devoted to testing / simulation used to select the proper glazing products and framing systems. Some of the causes of this unexpected condensation include:

- Outdoor conditions that are more severe (i.e., colder, windy) than those specified for the simulation or test.
- Air leakage through the framing system.
- Indoor environmental conditions that are different than those specified for the simulation or test. For example, if the specified indoor relative humidity is 40%, but actual RH% is higher, condensation may occur.
- Variations in the room's interior space such as:
    - Partitions, shades, obstacles, heat vents, etc. that influence air movement across the glass surface.
    - Plants, aquariums, vaporizers, etc. that increase relative humidity often only in the microclimate adjacent to the glass.

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While this document has focused on condensation on the indoor surface of glass, it should be recognized that condensation could also occur on the outdoor glass surface. This is more likely to occur with today's high performance low-e coated glasses. It does not constitute a problem with the glass, but rather indicates the glass is performing as intended to reduce heat loss. Please refer to Vitro's TD-102, "*Outdoor Condensation on Glass"* for further discussion in this regard.

The graphs shown on the following pages can assist in the evaluation of various Vitro glass products for the potential for condensation on the indoor glass surface. These graphs are intended to only be a guide to help in the selection of candidate products to meet specified design requirements.

The final product selection must be subjected to the more rigorous procedures of either the AAMA or NFRC methodology, or other similar methodology that is acceptable to the design professional.

While the graphs are labeled, the following points are emphasized to ensure that the user clearly understands what is shown.

- ► The curve (in red) represents the relationship between the indoor glass surface temperature when equal to the dew point and the relative humidity at which condensation would be predicted to form.
- ► Three graphs with different outdoor temperatures have the same specified design conditions as follows:

Specified Design Conditions			
Design Condition	Graph #		
	1	2	3
Outdoor Air Temperature (°F.)	-20	0	+20
Outdoor Air Velocity (mph)	15	15	15
Indoor Air Temperature (°F.)	70	70	70
Indoor RH% (winter)*	40	40	40
Indoor Air Velocity (mph)	0	0	0

* Comfort range for indoor RH% in winter is 30 - 40

- ► The Vitro glass products shown on the graphs are plotted by the predicted **center-of-glass** indoor glass surface temperature in a standard 1" IGU as generated by the LBNL Window v7.8.74 computer simulation program. The output data from this simulation under the specified design conditions is shown below:

GRAPH #1 – *Outdoor Air Temperature @ -20°F*

Glass Product	RH%	Dew Pt	S4 °F
Clear /Tinted/Solarcool®	40	44.6	37.0
Sungate® 400	40	44.6	46.3
Sungate® 400 + Sungate ThermL™	40	44.6	35.0
Solarban® 60	40	44.6	47.8
Solarban® 60 + Sungate ThermL™	40	44.6	36.7
Solarban® 70	40	44.6	48.1
Solarban® 70 + Sungate ThermL™	40	44.6	37.1
Solarban® 90	40	44.6	48.0
Solarban® 90 + Sungate ThermL™	40	44.6	37.0

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GRAPH #2 – *Outdoor Air Temperature @ 0℉*

Glass Product	RH%	Dew Pt	S4 deg F
Clear /Tinted/Solarcool®	40	44.6	**44.1**
Sungate® 400	40	44.6	52.2
Sungate® 400 + Sungate ThermL™	40	44.6	**42.8**
Solarban® 60	40	44.6	53.6
Solarban® 60 + Sungate ThermL™	40	44.6	**44.5**
Solarban® 70	40	44.6	53.9
Solarban® 70 + Sungate ThermL™	40	44.6	44.9
Solarban® 90	40	44.6	53.8
Solarban® 90 + Sungate ThermL™	40	44.6	44.8
Clear/Tinted/Solarcool® w/Argon	40	44.6	45.1
Solarban® 60 w/Argon	40	44.6	56.1
Solarban® 70 w/Argon	40	44.6	56.4

GRAPH #3 – *Outdoor Air Temperature @ +20℉*

Glass Product	RH%	Dew Pt	S4 deg F
Clear /Tinted/Solarcool®	40	44.6	50.9
Sungate® 400	40	44.6	57.5
Sungate® 400 + Sungate ThermL™	40	44.6	50.2
Solarban® 60	40	44.6	58.7
Solarban® 60 + Sungate ThermL™	40	44.6	51.6
Solarban® 70	40	44.6	59.0
Solarban® 70 + Sungate ThermL™	40	44.6	52.0
Solarban® 90	40	44.6	58.9
Solarban® 90 + Sungate ThermL™	40	44.6	51.9

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LEGEND FOR USE WITH GRAPHS Simulated Product: 1" Insulating Glass Unit with ¼" Glass for Both Lites and ½" Airspace - *Except as Noted*	
SYMBOL	**PRODUCT REPRESENTED**
●	Clear, Tint, Solarcool® coated glass
▲	1/8" Clear, Tint, or Solarcool® glass w/ – 95% Argon fill – 1/8" Clear (Graph 2 only)
○	Sungate® 400 coating on #2 or #3 surface
○	Sungate® 400 coating on #2 and Sungate ThermL™ coating on #4 surface
○	Solarban® 60 coating on #2 or #3 surface
△	1/8" Solarban 60 Coating on #2 or #3 surface – 95% Argon fill – 1/8" Clear (Graph 2 only)
●	Solarban® 60 coating on #2 and Sungate ThermL™ coating on #4 surface
○	Solarban® 70 coating on #2 or #3 surface
△	1/8" Solarban 70 Coating on #2 or #3 surface – 95% Argon fill – 1/8" Clear (Graph 2 only)
○	Solarban® 70 coating on #2 and Sungate ThermL™ coating on #4 surface
●	Solarban® 90 coating on #2 or #3 surface
●	Solarban® 90 coating on #2 and Sungate ThermL™ coating on #4 surface

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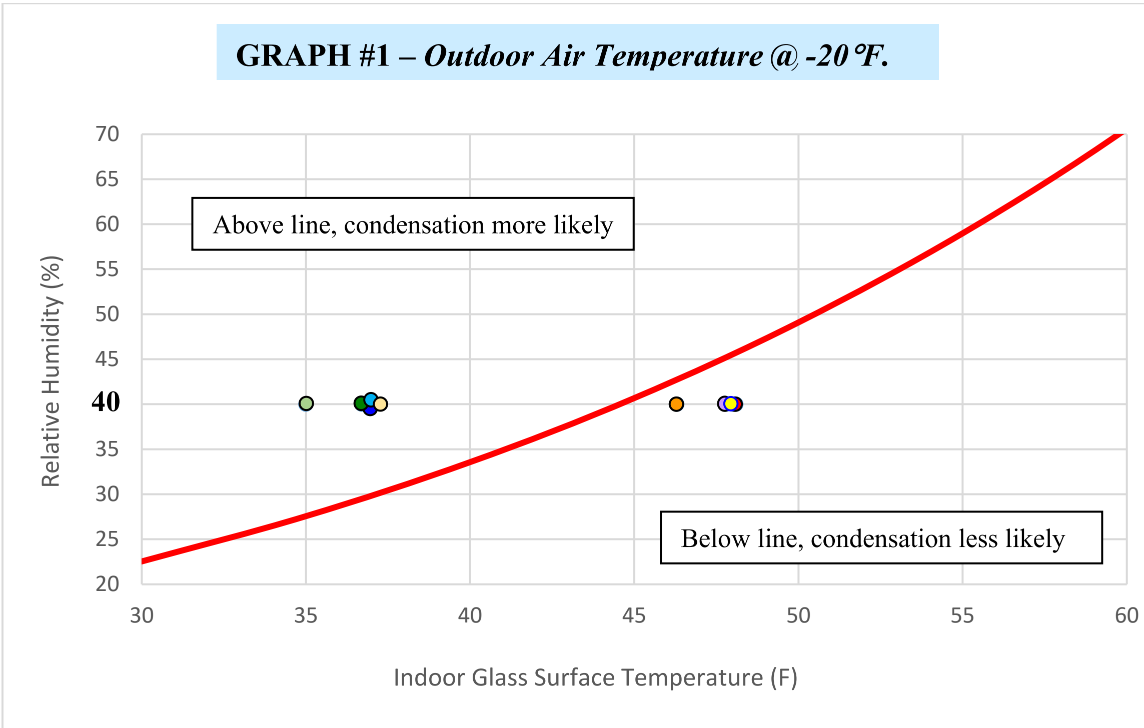

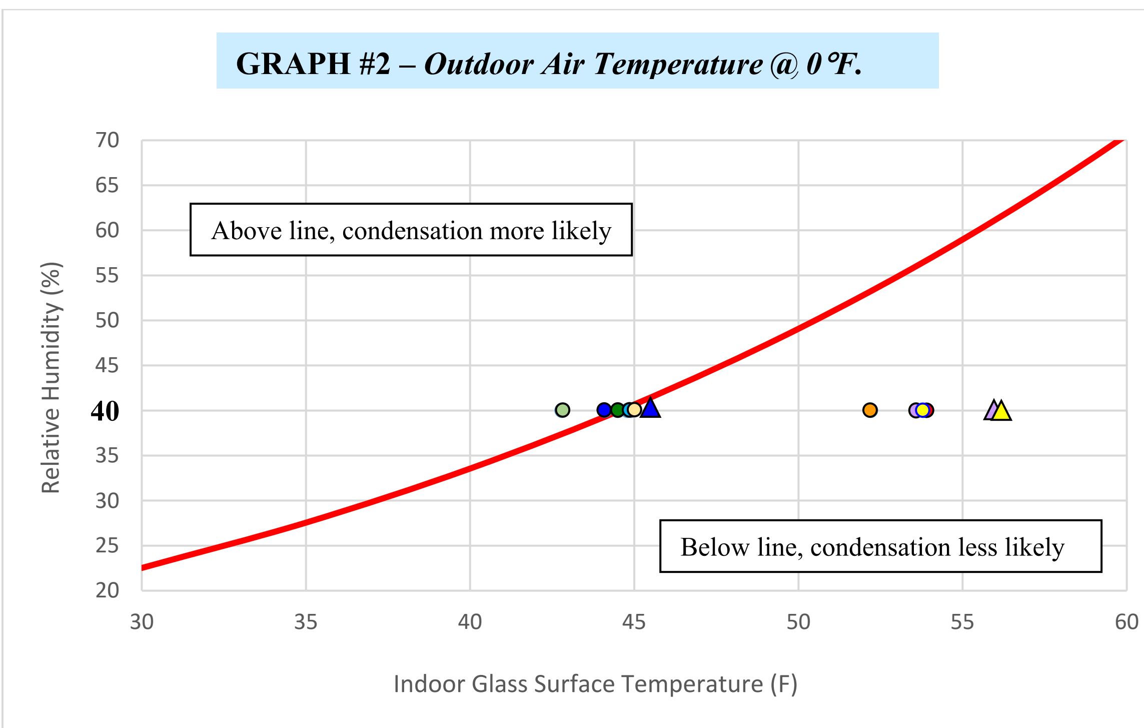

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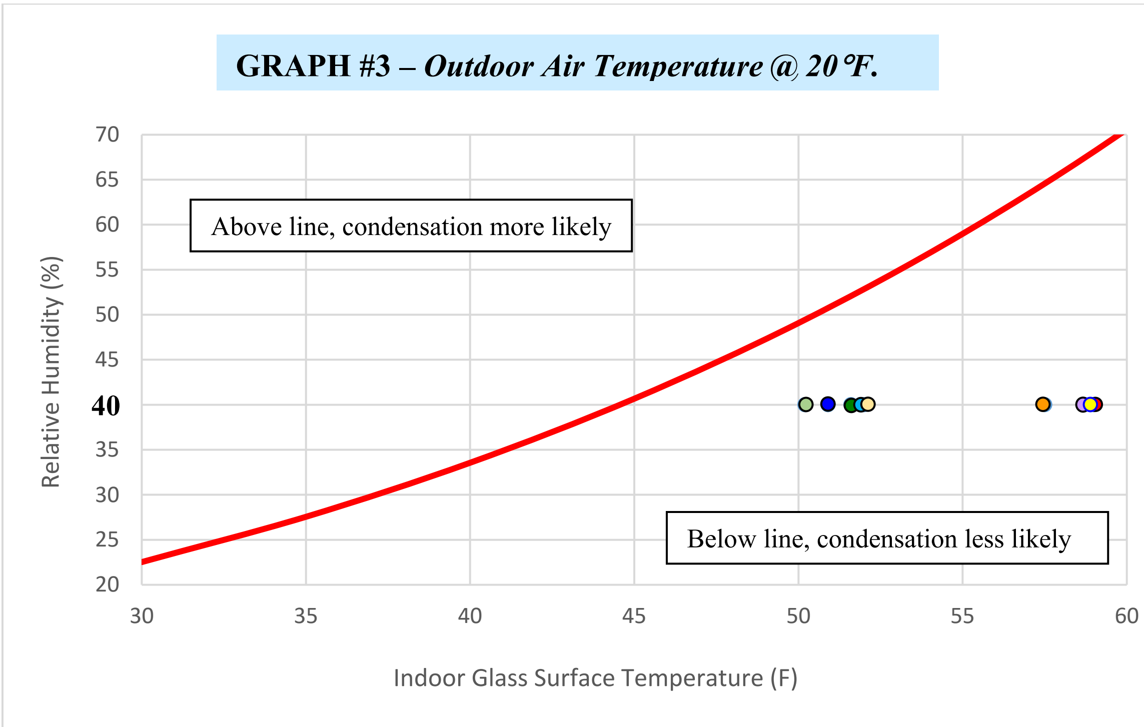

Additional Resources:

1. Dew Point Calculation tool - Dew Point Calculator (http://www.dpcalc.org)
2. National Fenestration Rating Council Technical Document Library - NFRC Technical Documents (https://nfrccommunity.org/page/TD)
3. NFRC tool for calculating LEAFF (the Linear Energy Analysis for Fenestration) - LEAFF Calculator (https://nfrccommunity.org/resource/resmgr/leaff_ci_docs/2022/NFRC_Benchmark_LEAFF_Spread.xlsx)
4. NFRC Condensation Index User Tool Manual - NFR19001_CI User Manual (https://cdn.ymaws.com/nfrccommunity.org/resource/resmgr/leaff_ci_docs/2022/nfr19001_ci_user_manual_v2_0.pdf)
5. Lawrence Berkeley National Laboratory glazing simulation programs Window/Therm - Software Tools - Windows & Daylighting (https://windows.lbl.gov/software-tools)

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HISTORY TABLE		
ITEM	DATE	DESCRIPTION
Original Publication	3/21/2003	TD-133
Revision #1	10/04/2016	Updated to Vitro logo and format
Revision #2	1/25/2019	Updated the Vitro logo and format
Revision #3	2/15/2024	Updated AAMA & NFRC referenced info; revised causes of condensation; updated Vitro glass products used to incl Sungate ThermL™ coating on #4 surface; revised graphs and added data tables; add Resource list

This document is intended to inform and assist the reader in the application, use, and maintenance of Vitro Flat Glass products. Actual performance and results can vary depending on the circumstances. Vitro makes no warranty or guarantee as to the results to be obtained from the use of all or any portion of the information provided herein, and hereby disclaims any liability for personal injury, property damage, product insufficiency, or any other damages of any kind or nature arising from the reader's use of the information contained herein.

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