NSG GROUP

Technical Bulletin

ATS-138 D
2013-01-14

Energy Efficient Window Design with Multiple Low-Emissivity Coatings

Summary

A single sheet of non-coated 3 mm (1/8 in.) annealed clear glass only keeps out the wind and the rain. It offers little insulation: Glass is thermally conductive. A glass mug of fresh coffee soon feels uncomfortably hot to the hand because excessive heat flows quickly from the hot coffee, through the glass container, to the cooler hand.

What is not so readily appreciated is that radiant heat is also transferred quickly to and from glass. Non-coated glass has a high emissivity value of 0.84. That means its radiating efficiency is 84% of that of a perfect 'Black Body' radiator. Cool glass both absorbs Infra Red (IR) room temperature heat, and radiates it on outwards to colder areas, with very high (84%) degrees of efficiency. (Note: although glass is opaque to this IR radiant heat it still does not insulate against its transfer. IR heat is simply absorbed at one surface, passes by conduction through the glass thickness, and then is re-radiated from the next surface.) Taken together, the high conductivity and the high emissivity of glass, mean that by itself, single glazed, non-coated, window glass is not effective as a thermal insulator.

However, all windows can benefit from higher insulation values (lower U-Factors (conductivity)), in all climates and in all seasons. This bulletin shows a simple way of improving the insulation value of glass by adding multiple low-e coatings, without altering the dimensions of window frames or hardware details

Note: Daylight Transmission (Tvis) and Solar Heat Gain (SHGC) are separate window characteristics from the U-Factor. Different installations can require Tvis and SGHC to be high, low, or even variable. For optimum passive solar gain in heating dominated climates the use of high solar gain low-e coatings is generally more beneficial. For cooling dominated climates, a low solar gain low-e coating should typically be used on the #2 surface. For high or low solar gain clear windows, adding a hard low-e coat to #4 surface, has little effect on Tvis or SHGC.

Pilkington North America, Inc.

811 Madison Avenue, Toledo, Ohio 43604-5684

Telephone 800 221 0444   Fax 419 247 451

REDUCING HEAT FLOW BY REDUCING THERMAL CONDUCTIVITY

Nothing can be done to reduce the high thermal conductivity of glass as a material. Even laminating 2 plies of 3 mm (1/8 in.) glass with a relatively low thermally conducting 0.7 mm (0.030 in.) pvb interlayer only reduces the Winter U-Factor by 2% because the pvb interlayer is not thick enough to be effective.

The thin boundary layer of almost stationary air at most glass surfaces does supply insulation. An open honeycomb glass surface would increase the thickness and effectiveness of this air insulation layer, but it would impair the optical quality. Instead, the deployment of additional lights of glass is used to multiply the number of insulating boundary air layers. Roughly speaking, adding 1 or 2 more lights to single glazing, with 12 mm (1/2 in.) gap(s), doubles or triples the overall air-to-air resistance to unwanted heat flow.

REDUCING RADIATIVE HEAT TRANSFER BY REDUCING SURFACE EMISSIVITY

More heat is transferred between the inner and outer lights of a double glazed unit (DGU) by radiation, than by convection/conduction of the gas in the sealed space between the lights. This major component of unwanted heat transfer can be reduced by applying visibly transparent low-e coatings.

Low-e coatings are not significantly effective on the outer #1 surface because the greater part of the heat transfer there (between the #1 surface and the exterior surroundings) is due to the natural air convection flow of the ambient wind.

The most important area to place the first low-e coating in an IG unit is within the sealed air/gas space. Radiant heat transfer is proportional to the effective emittance between two surfaces: Eeff = (E2 x E3) / (E2 + E3). Uncoated glass has a very high emissivity value of 0.84 so the addition of one low-e coating (typically in the range 0.04 to 0.20) to only one of the two surfaces (#2 or #3 in a DGU)) will greatly reduce the radiant heat transfer between them. The following table shows that little significant improvement is realized by using two low-e coatings facing each.

EFFECTIVE EMITTANCE (Eeff)

E2\E3	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**
0.1	0.05	0.07	0.08	0.08	0.08	0.09	0.09	0.09
0.2	0.07	0.10	0.12	0.13	0.14	0.15	0.16	0.16
0.3	0.08	0.12	0.15	0.17	0.19	0.20	0.21	0.22
0.4	0.08	0.13	0.17	0.20	0.22	0.24	0.25	0.27
0.5	0.08	0.14	0.19	0.22	0.25	0.27	0.29	0.31
0.6	0.09	0.15	0.20	0.24	0.27	0.30	0.32	0.34
0.7	0.09	0.16	0.21	0.25	0.29	0.32	0.35	0.37
0.8	0.09	0.16	0.22	0.27	0.31	0.34	0.37	0.40

The addition of a single low-emissivity coating to one of the two inner surfaces (putting it on either #2 or #3 gives an equal reduction in radiant heat transfer) turns a DGU into a high performance insulating product. The next significant improvement in U-Factor is gained by using an insulating gas (such as Argon) instead of air.

The most valuable location for a second low-e coating in a double glazed unit is on surface #4 where an 18% improvement in U-Factor can then be immediately gained.

GLASS TEMPERATURES AND CONDENSATION ON THE ROOM-SIDE SURFACE

The following temperatures (calculated with LBNL Window 6 program), RH values and Dew Points are for the ASHRAE/NFRC standard winter conditions of -18°C (0°F), and 5.5 m/s (12.3 mph), wind.

(An extreme winter condition of -30°C (-22°F) can be used for Northern Minnesota, Saskatchewan and Manitoba to show similar differences between different glass types)

The temperature of a single glazed window of non-coated glass will be below freezing in winter and would probably have frost on the inside #2 surface under normal occupancy conditions.

#2 Surface Winter Temperature	Max. Room RH at 21°C (70°F) for no condensation to occur
-9.4°C (15°F)	12%

Changing from single glazing to non-coated double glazing with a 12 mm (1/2 in.) air fill reduces the window heat loss from the room by 57%. The room-side glass surface (#4) temperature now rises to well above freezing: 6.5°C (44°F), where no condensation occurs on the central area (more that 50 mm (2") in from the sight-line glass edge) area unless the 21°C (70°F) room air Relative Humidity (RH) rises above 39%.

#4 Surface Temperature	Max. Room RH at 21°C (70°F) for no condensation
6.5°C (44°F)	39%

39% RH is well above most typical living space humidity levels in winter, except perhaps in a non-ventilated bathroom, and then only while a hot shower is running. 30% RH is a common and comfortable indoor level, at 21°C (70°F) in winter.

Room Temperature	Rel. Humidity at 21°C (70°F) (RH)	Dew Point (Condensation (100% RH))
21°C (70°F)	30%	3°C (37°F)

30% RH at 21°C (70°F) will give condensation on a surface at 3°C (37°F) or colder. New houses, with improved air tightness and little or no ventilation, could reach higher RH levels in winter, especially with non-vented clothes washing and drying being performed within the space.

Condensation on glass will occur when its temperature falls below the dew point of the adjacent air. In standard winter conditions, outside air is -18°C (0°F). Taking a worst case of 100% RH outside: when that air comes into a house it is heated to 21°C (70°F).

Air Temp.	Relative Humidity at 21°C (70°F)	(RH) Dew Point (Condensation (100% RH))
-18°C (0°F)	5%	-18°C (0°F)

Until humidification is added, this same air when brought into a house now has a very low RH of about 5%. People, pets, cooking, washing and humidifiers all contribute humidity to some extent, raising the RH value before that stale air is exhausted and replaced by more dry air.

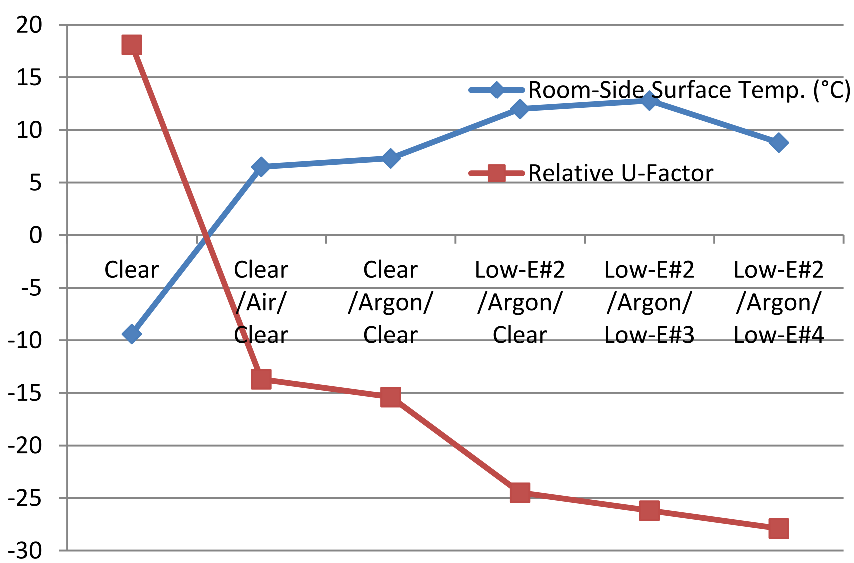
An optimum combination of a generic double silver soft sputtered Low-E on surface #2, argon gas fill and pyrolytic Pilkington **Energy Advantage™** Low-E hard coating on surface #4 results in a U-Factor improvement of 81% as compared to the single glazed case. Note that while the addition of a low-e coating to #4 surface cuts the unwanted heat loss from the room it does inhibit the glass from being warmed by radiant heat. The net result is that the #4 surface glass temperature falls to 8.8°C (48°F). But this is still 2°C (4°F) warmer than the case of a non-coated, air-filled, double glazed unit. This means that the interior humidity would have to rise to 46% RH before condensation appears in the central glass area.

#4Surface Temp.	Relative Humidity at 21°C (70°F) (RH)	Dew Point (Condensation (100% RH))
8.8°C (48°F)	46%	8.8°C (48°F)

The graph below shows the Relative U-Factors (no units) and the room-side surface temperatures (°C) during ASHRAE/NFRC standard winter conditions of -18°C (0°F), and 5.5 m/s (12.3 mph) wind for different coating combinations. The graph shows the significant further gain in U-Factor achieved by the addition of a second low-e coating to a DGU.

The central glass area of a clear, non-coated, air-filled, properly manufactured, double glazed unit, with 12 mm (1/2 in.) air space has been demonstrated over the years to be warm enough to prevent center of glass condensation in normal residential winter conditions in North America. With this as a datum point it can be seen that adding low-e to the #4 surface of a low-e (#2 surface), Argon filled, IG unit will result in a slightly warmer center of glass area and even less possibility of condensation occurring there.

(Note: in years past, many sealed units were made with air spaces smaller than 12 mm (1/2 in.) or with inappropriate desiccants and poor manufacturing techniques which often resulted in significantly lowered pressure in the sealed air space. A resulting center of glass air gap of 6 mm (1/4 in.) or less, in cold weather, could then readily cause central glass area condensation).



If winter condensation is seen on the #4 surface of sealed units, low-e coated or not, it first occurs at the coldest areas, typically near the glass edges (within 50 mm (2 in.)) where the cold glass temperature is primarily determined by the lesser insulation values of the IG spacer and window frame materials rather than by any coating on the glass.

Of course if a double glazed unit were incorrectly made with a low-e coating ONLY on surface #4 then the room-side glass surface winter temperature would fall to 1.8°C (35°F) - barely above freezing. At this temperature, condensation would occur when the room RH was at or above 28%.

#4 SurfaceTemp.	Room RH at 21°C (70°F)	Dew Point (Condensation (100% RH))
1.8°C (35°F)	28%	1.8°C (35°F)

EXTERIOR SURFACE (#1) CONDENSATION

High insulating performance windows can have occasional exterior surface condensation, especially in the early morning, with still air, high exterior humidity and a cloudless night sky. This condition is temporary and does not lead to mould formation or damage in a properly designed window frame. For a more detailed explanation see ATS Bulletin #161, Architectural Technical Bulletins

IG FABRICATION

As detailed in ATS Fabrication Bulletin #135, Architectural Technical Bulletins the pyrolytic coating is hard and durable. However dragging metal tape measures, rubber suction cups, or sliding the coating on rollers or insulating glass (IG) press equipment could be expected to make deposit type marks on the very fine texture of the coating which will need to be removed. Direct contact with rollers, suction cups, press platens etc., will not create such marks.

Similarly, applying adhesive labels to the very fine texture of the hard pyrolytic coating will not damage the coating, but could create cleaning issues if the adhesive can separate from the label and lodge into the valleys of the surface texture. Organic solvents can be used to remove such adhesive residues without any damage to the hard coating but it is obviously preferable to avoid applying such labels unnecessarily to the coated surface. If labels are used on the coated surface they should only be in place for the least time needed. They should not be left in place when sunlight can shine through the glass to the adhesive material causing it to change. Labels should be thoroughly tested for ease of complete removal after time.

IG TRANSPORT

Transportation should be made without any sliding action occurring between the coated surface and any packing materials.

INSTALLATION

Either install the glass after other cement, mortar, plastering and painting trades have completed their work, or protect the coated surface from splashing and overspray of these materials. Such materials will typically not damage the pyrolytic coating, but their effective removal may be difficult resulting in glass and coating scratching or marking.

MAINTENANCE & CLEANING

See Architectural Technical Bulletins ATS #143 for normal manual cleaning procedures noting the prohibitions against the use of razor blades, metal scrapers, steel wool, etc.

COATING DURABILITY

The Pilkington **Energy Advantage™** coating has been successfully tested to the European EN 1096-2 standard for exposed coatings. This standard includes sections on resistance to: abrasion; acid rain; condensation and salt spray cycling.

The toughness and durability of the coating has been well demonstrated by the many installations in Australia of residential, single glazed, patio doors with a solar control layer under the same top surface low-e coating. This application has now proven to be successful for more than 10 years installed life.

See Pilkington website "Sun Management Calculator" at http://www.pilkingtoncalculators.com/smc.php for performance values of double glazing with low-e coatings on multiple surfaces. A one-page brochure, "Low-E 4th Surface Technology by Pilkington Glass", with performance data is at:
www.pilkington.us/energyadvantage

Pilkington North America, Inc.

811 Madison Avenue, Toledo, Ohio 43604-5684

Telephone 800 221 0444 Fax 419 247 4517