Technical Bulletin

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Glass Selection and Design with Pilkington **OptiView™** Anti-Reflective Glass

Summary

All transparent glass has some reflection value and some transmission value. Good glazing design will select an appropriate glass and coating for a particular application.
When looking at any flat or bent glass installation one's eye simultaneously sees a transmitted image and a reflected image. It is the combination of those two images that often gives the material its "glassy" appearance. If one of the two images is more than 50 times brighter than the other, then the human brain only perceives that stronger image.

In the image above of the Toledo Museum of Art Glass Pavilion™, with non-coated Pilkington **Optiwhite**™ clear double glazing, the bright transmitted image of the art glass furnace is clearly seen near the center of the picture. There is a slight distraction or masking from the faint reflection of the dark, shaded area of trees behind the camera. On the right hand side of the picture the strong reflection of the sky and daylight trees, especially when seen in glass at an angle to the viewer, completely overwhelms any transmitted image.

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GLASS REFLECTIONS

A successful 'Transparent Mirror' installation partly depends on controlling the brightness of items seen in transmission and reflection to obtain the desired effect. Pilkington **Mirropane**™ Glass has a coating and a glass tint with optimized transmission and reflection properties to provide the required transparent mirror performance with the minimum difference in controlled light levels on either side of the glass. The cut-away glass in the picture below simulates both properties.

ANTI-REFLECTIVE GLASS

There are many design situations where reflected images need to be reduced as much as possible, such as in storefront windows, observation booths, display cases, etc., while providing maximum possible transmission. This is achieved with the appropriate use of low reflection coatings.

The left side of this display case glass is 6 mm plain, clear, glass with no coating. It clearly shows distracting reflections from other display cases behind the camera.

The right hand half of the display case is glazed with laminated Pilkington **OptiView**™ Anti-Reflective coated glass which effectively eliminates the distracting reflections, and increases the transmission by 4%.

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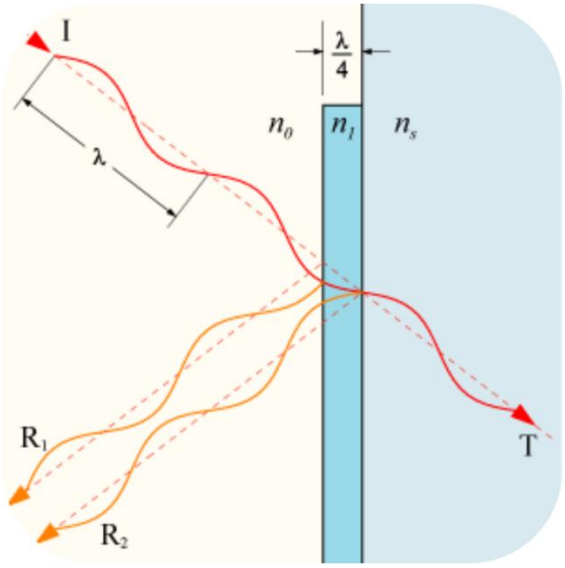
The application of low reflection coatings not only reduces distracting reflections, but also increases the amount of light transmitted and thus increases the brightness of observed images.

It is important to realize that reflections occur wherever relatively dense glass (or water) contacts much less dense air. The reflection at such interfaces is about 4% (or more when viewed at a grazing angle). But a piece of clear glass (with 92% transmission) has two such interfaces. For flat glass with parallel surfaces, the two reflections align with each other so that they seem like one and will have an apparent 8% brightness. That means that the transmitted image, when directly viewed through the glass, is about 92/8 or 11.5 times brighter than the observed reflected image (when both are lit with equal power illumination).

Finely tuning a transparent glass coating, made of a material with a suitable index of refraction, makes the coating thickness about ¼ the wavelength of light. The two equal magnitude reflected waves (R1 and R2), from the top and bottom of the coating, then completely cancel each other. The result is no reflection. See picture below from www.wikipedia.com



Unfortunately white light is composed of different colors with different wavelengths (from about 400 to 700 nm). And glass is viewed at different angles changing the apparent thickness of a coating, so the construction of a typical low reflection coating for glazing can only reduce the average reflection at one surface from 4% to about 1%, rather than completely eliminating it.

For a piece of flat, parallel glass, with air on each side you will need a low reflective coating on both surfaces. (Placing a low reflection coating on just one surface only reduces the reflection from about 8% down to 5%. This much reduction is generally not observably significant). But coating both surfaces will reduce the original total reflection from 8% down to about 2%. Under many lighting and viewing conditions this 4 times reduction can effectively eliminate visible reflections.

The approximate 4% points increase in transmission with the low reflection coatings on each surface now means the transmitted image is about (92+4)/2 or 48 times brighter than the reflected image (instead of only 11.5 times brighter as before).

Pilkington **OptiView**™ low reflective glass is manufactured with a pyrolytic coating only on the float glass top surface. An effective low reflection glazing product is then made by laminating two coated plies, or layers, back-to-back to obtain a single laminated glass light with anti-reflective coatings on both glass/air interface surfaces.

Good glazing design will take account of the brightness of the items whose reflection is to be diminished. Street scenes or interior walls can generally have their reflection brought to a negligible level once they have been reduced by a factor of 4 by anti-reflection coatings. But a bright, point source of light such as the sun or an individual light bulb, is too bright to have its visible reflection effectively eliminated by a simple 4 times reduction. The solution for this situation is to position the glass and control its installed angle of tilt so that bright reflections are not seen by viewers in their typical occupancy locations. A very common example of this solution is in aircraft control tower glazing where the sloped glass reflects a barely visible image of an unlit matt black ceiling rather than the reflection of the bright outdoors, behind the observer, which would be seen with vertical glass.

Exterior view showing glass tilted out at the top of an aircraft control tower.

The view from the tower interior showing minimal distracting reflections.

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Pilkington **OptiView™** Anti-Reflective glass has a permanent coating of thin, clear, hard, pyrolytically formed, Silica and Tin Oxide layers on one side. This coating reduces the normal reflection of a glass/air interface from 4% to about 1%. For an aquarium, where there is only one air/glass interface, a single coating of Pilkington **OptiView**™ can be used, because there is no reflection from the glass/water interface. But for building glazing applications low reflective coatings are needed on all glass/air surfaces. The glass is normally fabricated with two coated plies in a laminated light. The laminate, with low reflective coatings on laminate surfaces #1 and #4, will reduce the 8% reflection of single, clear, non-coated glass to a visible light reflectance of about 2%. Note: there is no visible reflection from laminate surfaces #2 and #3 because they are in contact with the interlayer material (pvb or other) which has a refractive index very similar to that of glass.

The use of laminated glass brings added benefits of safety, security, building envelope integrity, acoustic insulation when compared to monolithic glass, and improved optics (less distortion) when compared to heat treated safety glass.

The stadium example below shows an excellent application of single glazed, annealed laminate, with two plies of Pilkington **OptiView**™ for all the vision glass in the upper level boxes. The photo, taken through the glass from an occupant's normal position, shows the clear, 4% greater transmission, view, without distracting interior reflections.

The spandrel areas above and below the vision glass, on both sides of the stadium (see the 2 photos below) are single glazed, monolithic, tempered Pilkington **OptiView**™ with the low reflective coating on the outside (#1 surface). The inside (#2 surface) is a dark blue color with

fired-on ceramic frit. The dense ceramic frit gives no mirror or specular reflection at the glass/frit interface. The desired (in this particular installation) dark blue color seen is a diffuse reflection from within the body of the frit material. In this example the specular reflection of the spandrels is reduced to about 1%.

The two photos below show a striking increase in reflection observed when plain, non-coated glass was temporarily used during construction: the left image has plain glass in the one bottom left light of the 8 specified low reflective vision panels; in the right hand picture of 8 specified anti-reflective spandrels, the two, top row, right side pieces, are plain glass. The use of low reflective glass was needed for the whole stadium project when ray-tracing work revealed that certain times and dates during the playing season would allow overly bright direct solar reflections from plain glass directly onto the playing and spectator areas.

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ANTI-REFLECTIVE DOUBLE GLAZING

For double glazing, with four glass/air interfaces, the visible reflection is about 4 x 4% = 15 or 16%. It can be readily appreciated that four anti-reflective coatings are needed (by using two laminates) to effectively reduce the overall reflection by a factor of four to about 4%. With clear glass, the reflections coming through from the further back surfaces are just as visible as those from the front surfaces. Thus only using 2 or 3 anti-reflective coatings, instead of 4, would only reduce a double glazed unit reflection to about 10% or 7%. This improvement from the original 15 or 16% is seldom worthwhile when compared to the possible four times reduction in reflection that can be achieved when all glass/air surfaces have low reflection coatings.

Chico's store above, on the extreme left, is glazed with Pilkington **OptiView**™ double glazing (2 laminated lights, of 2 plies each) with about 4% visible reflection.

Ann Taylor's windows above are double glazed clear glass giving about 15% reflection which mask the details of the display items in contrast to the clearly visible display in Chico's window on the left side.

As with most transparent coatings there are some residual reflected and transmitted colors faintly visible under certain conditions, and at certain off-normal viewing angles, mostly caused by optical interference effects. For applications where visibility of true colors needs to be optimized for maximum fidelity it is often preferable to simply use Pilkington **Optiwhite™** low iron glass, without any coating. This eliminates any green tint, and prevents any possible faint coloring of reflected or transmitted images by the coating, especially when viewed at an angle. By controlling the geometry of the installation so that any reflected areas visible in the glass are dimly lit, a highly visible, true color, transmitted images can be best obtained.

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Pilkington's **OptiView™** Anti-Reflection coating has a reduced emissivity value of 0.46 compared to that of 0.84 for non-coated glass. Using it on all four surfaces of an insulating glass (IG) unit gives the same U-factor improvement as applying a single coating of Pilkington **Energy Advantage**™ low-e glass. The Pilkington **OptiView**™ coating is smoother, but will show finger prints more readily, than Pilkington **Energy Advantage**™ low-e. Such marks can be readily removed by normal manual cleaning methods.

Contact Pilkington North America, Inc. Architectural Technical Services, tel: 419 247 4448 for further information.

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