PILKINGTON

Technical Information

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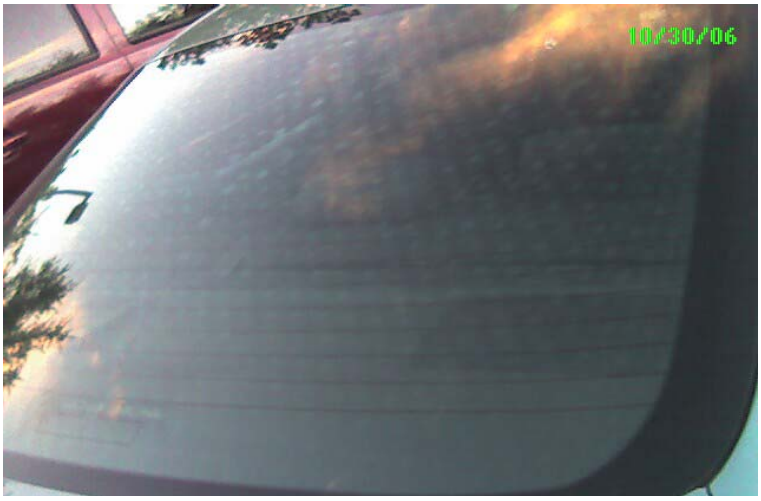
The Appearance of Quench Marks in Heat Strengthened and Tempered Glass

When viewed under particular lighting conditions, especially when viewed at a grazing angle, faint shadowy spots and lines caused by the air quench process can often be seen in heat treated glass. These spots can be seen in transmission and in reflection, and at most viewing angles, other than directly facing the glass. They become very visible when polarizing sunglasses are worn. They are easily seen on a sunny day when the light comes from a dry blue sky or is reflected from clouds. They are less visible on a grey, cloudy day. These spots and lines are a normal function of properly tempered glass and are mentioned in section 7.5 of ASTM C 1048 standard for heat-treated glass. They are more visible in thicker, clear, heat treated, glass; when a lightly reflective coating is used; or when both lights of glass in an insulating glass (IG) unit are heat treated. They are often seen in the single glazed, monolithic, sloping tempered back windows of cars. In Asia they are often very obvious in some small truck tempered flat windshields.

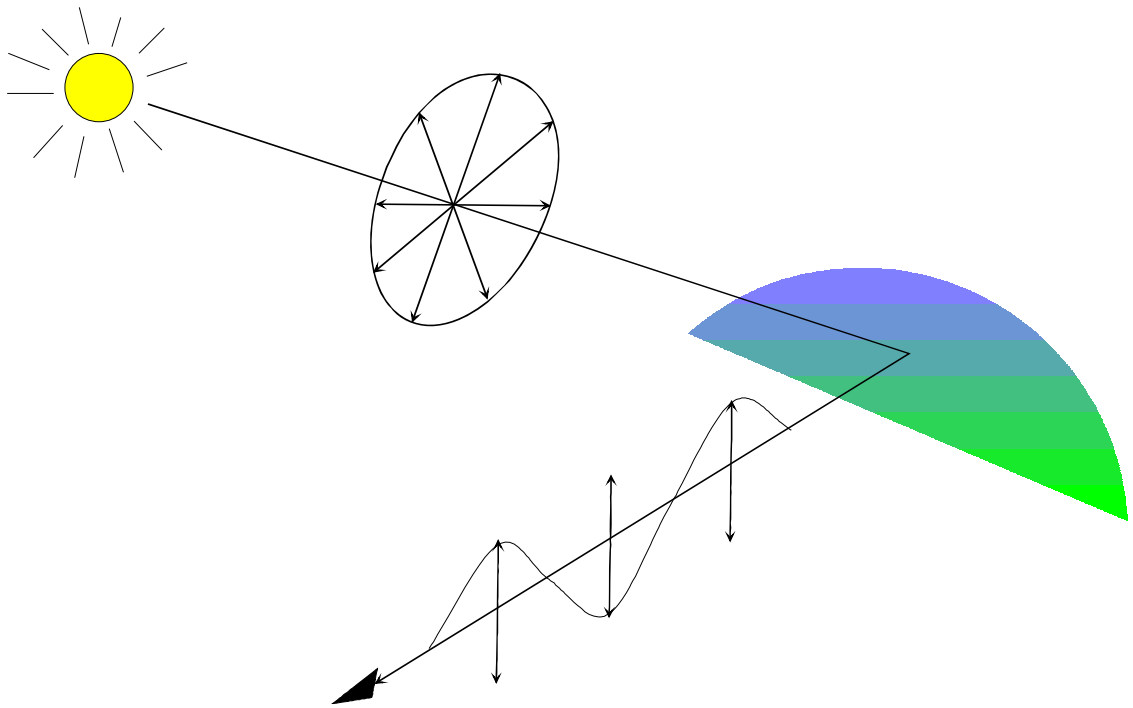
These 2 lights of 12 mm tempered glass in a sliding door at the Pittsburgh airport Hyatt hotel entrance, shown open with one light behind the other, display a strong quench pattern to the naked eye (no Polaroid filter). The incoming light (from lower left) is polarized by reflection off the polished stone floor; further reflections, again at Brewster's angle off the glass, add to the constructive/destructive interference effects.



Typical dot quench pattern seen in a tempered Mercedes automotive back window when incoming light is reflected from the sky, especially when the sun is not directly shining on the glass.

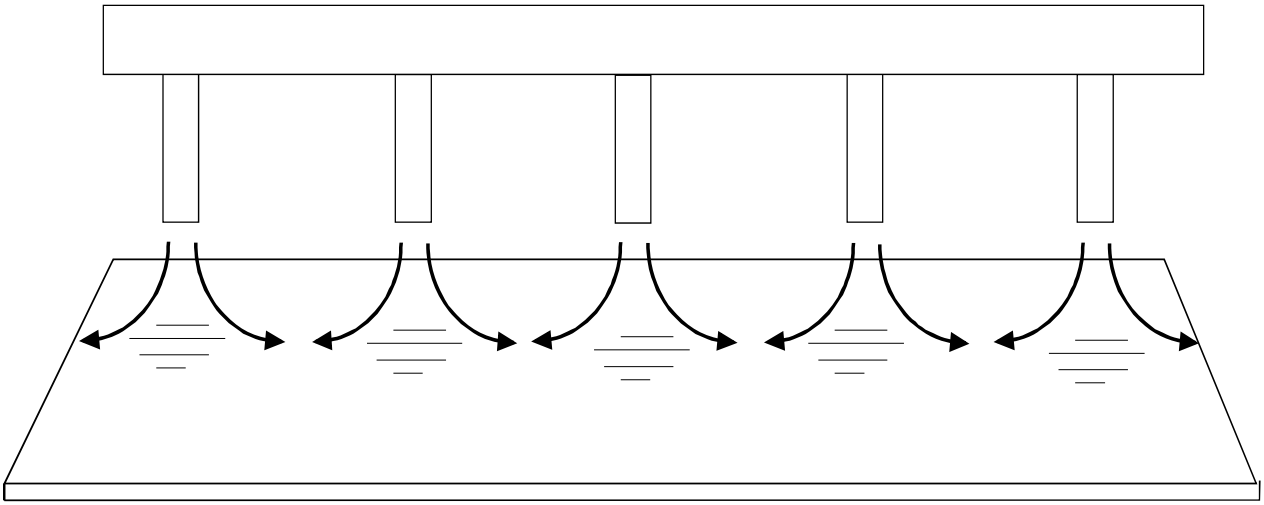
The illustrations below show a simplified explanation of the physics involved in their formation:

Illustration #1 shows how light coming from the sun is made up of oscillating waves in planes at different angles to each other. When sunlight reflects from molecules of air it becomes partially polarized. These polarized waves vibrate mostly in one plane at a particular angle to vertical.



Polarization of Sunlight by Interaction with Blue Sky

Illustration #2 shows how the quench jets in a tempering furnace cannot cool the glass completely uniformly. As a result some areas are cooled faster than others, resulting in differential shrinkage which creates areas of different compressive stress. When glass is stressed in the quenching operation, with its corresponding very slight changes in density, it becomes birefringant or polarizing: that is it rotates the angle of the plane of polarized light. The greater the stress the greater will be the rotation effect.



Tempering Quench Jets 2

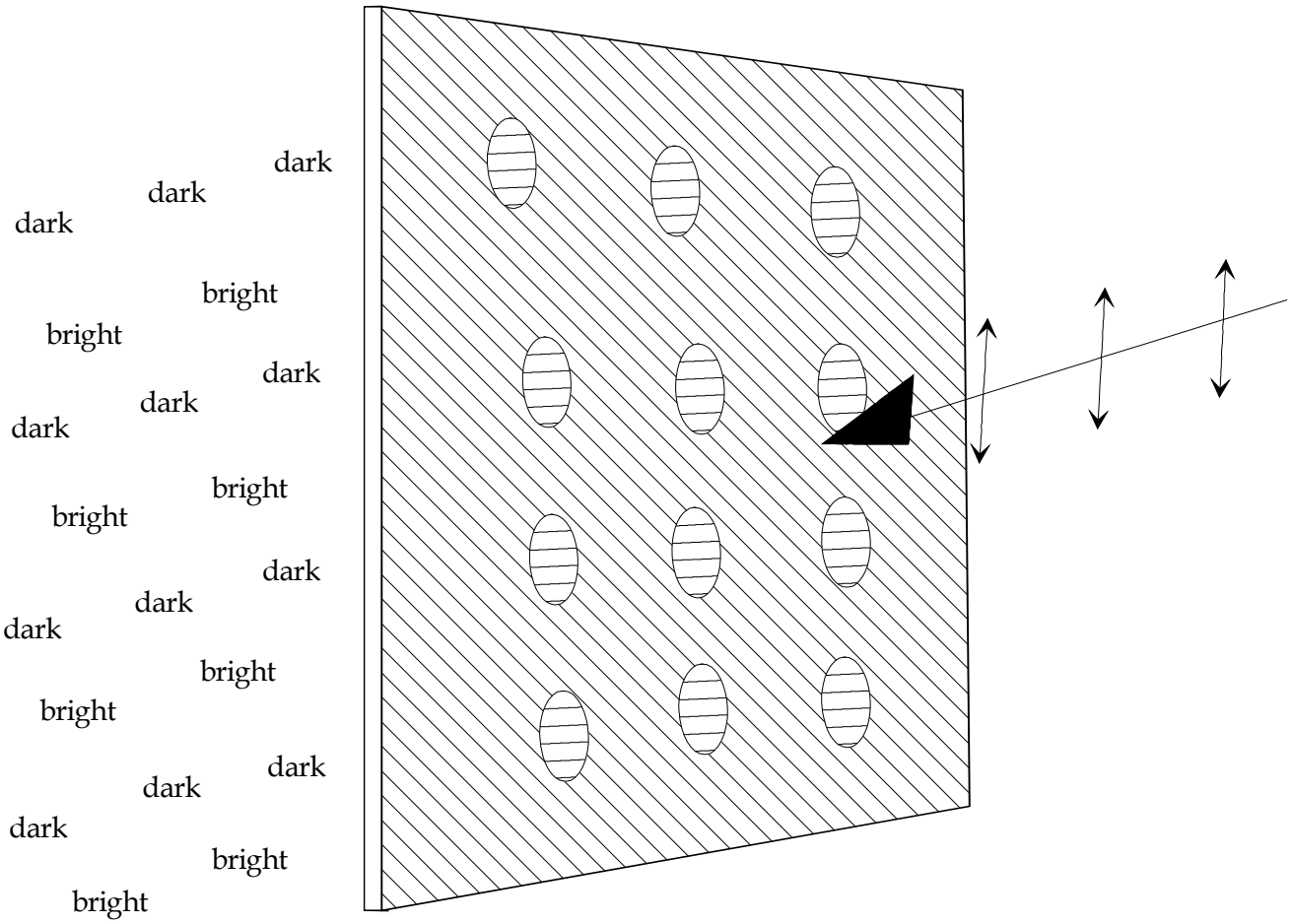
Formation of Quench Marks

In ordinary, non-polarized, light the quench marks can be best seen when looking at the glass at an incident angle (as measured from a vertical to the plane of the glass) of 56 degrees. At this angle (Brewster's) reflected light becomes fully polarized.

When polarized light, either from a blue sky or other reflection or from reflection at Brewster's angle at a glass-air interface, passes through stressed areas of heat treated glass its angle of polarization is rotated. When that light reaches the next glass-air surface a large amount may be lost, in both transmission and in reflection, depending on the angle of polarized rotation. Areas of the glass with relatively high and low stress will therefore locally transmit and reflect different amounts of light thus creating the familiar, spotty, quench mark pattern.

The loss of light when the polarized beam is not reflected, or not transmitted, results in the familiar irregular dark marks, visible in both transmission and in reflection.

Illustration #3 shows schematically (ignoring the details of Brewster's angle and glass-air reflections) how vertically polarized light could easily pass through vertically polarized sections of the glass to give bright spots but is diminished when passing through other areas polarized at a different angle to give relatively darker spots.



Polarized light through Tempered Glass 3

The spots are not an indication of absolute tempering level; they simply show areas of relatively more, or less, tempering stress. Given the nature of the quenching process it is physically impossible to quench a plate with absolute uniformity. The degree of tempering and the uniformity of tempering throughout the plate can be tested by other methods such as surface stress instruments or by examining the break pattern after fracture.

A 12inch square of 12 mm thick tempered glass can show its quench pattern to the naked eye, with no Polaroid filters, when viewed at appropriate angles on a blue sky day.

The same 12 inch square of 12 mm tempered glass much more readily shows the quench pattern under the same lighting and viewing conditions when viewed in reflection, with the transmitted image subdued by placing the glass on black velvet.

Conclusions

Visible quench patterns are an indication that the glass has been heat treated. They are not a defect. Architectural glass samples for building projects should be supplied with the specified heat treatment so that careful viewing can display the final appearance. If the samples are not heat treated, and the glass specified for the project is to be heat treated, then the samples should be appropriately and permanently marked to avoid confusion.