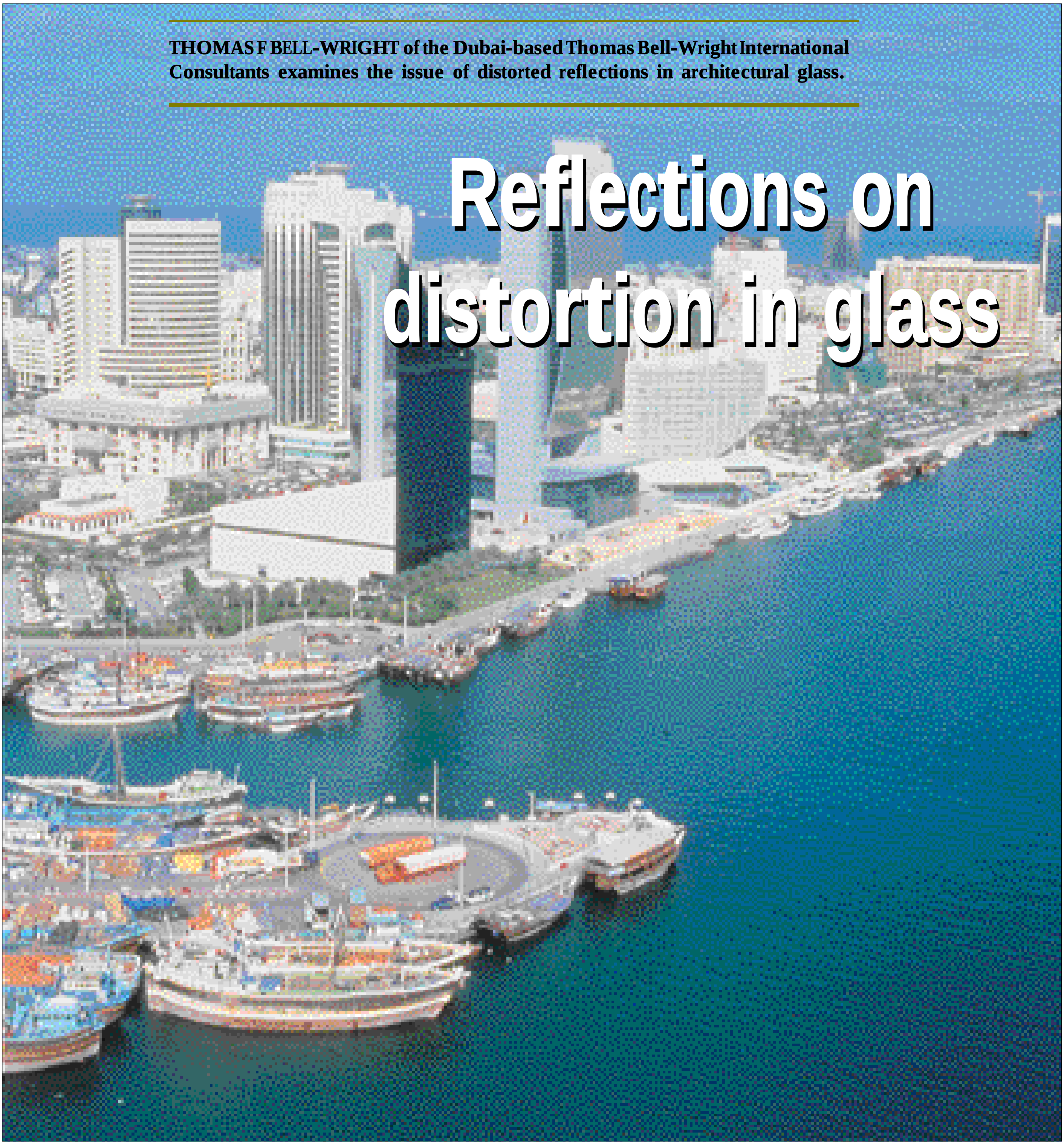
THOMAS F BELL-WRIGHT of the Dubai-based Thomas Bell-Wright International Consultants examines the issue of distorted reflections in architectural glass.

Reflections on distortion in glass



THERE is, in the UAE today, a fantastic number of glass-clad buildings. One of the characteristics of glass in buildings is its irregular reflections, so the subject may be of general interest. Some types of reflection produce a pleasing appearance, however several do not. I M Pei was reported to have ordered the polishing of the glass in the Louvre pyramid in Paris, France, because of such effects.

Firstly, there has to be a reflection of some object in order to discern any distortion. If there are (or will be) other buildings in the proximity of the glass, their reflection should be considered. The distortion is manifested, of course, by waviness in the lines of the reflection, and is caused by deviations in the flatness of the glass surface. There are a number of causes of this unevenness, some avoidable, some not. In certain projects, the 'beaten copper' appearance produced by fully-tempered (FT) glass is intended as an architectural feature. Much more commonly though, the distortion simply is believed to

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be an unavoidable part of this type of construction. While some distortion may indeed be unavoidable, it is also possible to reduce it in some instances.

What Causes Distortion?

Glass surface flatness is affected:
1) during its manufacture,
2) by air pressure forces that act upon it, and
3) by its installation.

The glass typically seen in structures is generally heat-treated, had a reflective coating applied, and was assembled into an insulating glass unit (IGU) also called double glazing. Raw glass, called 'float glass' because it is formed by floating the molten glass on a bath of molten tin, is relatively flat. Much glass surface deformation is a result of the heat treating process.

Resistance to wind loads, thermal stresses from sunlight, and breakage characteristics, can be modified by a tempering process in which the glass is heated to a plastic state and cooled in a controlled way. This process produces deviations in the flatness of the glass such as 'roller wave,' in heat-strengthened (HS) glass, as well as deviations which can be both local and over the whole piece. Typical glass standards permit quite large deviations from flatness: ASTM permits local bow or warp of 1.6 mm from flatness between points only 300 mm apart. Deviations are greater in FT glass than in HS; both are generally suitable in meeting thermal stresses, but FT glass should be used where a high degree of irregular distortion is desirable, or where safety glass is required. Otherwise, HS glass is generally preferable.

Insulating Glass

Insulating glass, where two panes of glass are hermetically sealed together to enclose an insulating air space (not a vacuum, as some people suppose), can lead to distortion from several sources. The manufacturing process should be done with the glass vertical. Unless using proper specialised equipment, it is somewhat easier to assemble the IGU lying flat on a table. The problem with this is that the upper panel of glass sags in the middle and then there is less air than there should be in the air space. When the glass is placed in the vertical position, the reduced air volume exerts a pressure on the glass and the glass on both sides bows in. The only way to correct this is to insert a breather tube which permits equalisation of air pressure when the glass is vertical, after which it is

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KEEP COOL WITH K-LITE

The thermal insulation performance of glass plays a key role in keeping energy costs low. ARTHUR MILLWOOD of Riyadh-based Saudi American Glass Factory provides guidelines on how to evaluate the performance of a chosen glass.

OVER the past decade, there has been a worldwide explosion in the number of glass manufacturers, and consequently in the variety of glass types, to meet the growing demand for architectural glass.

The dynamics of this situation has been, and continues to be, driven by two principal factors: the contemporary architectural fashion which requires large glazed openings in structures that appear to "float" and the rising cost of energy for heating and/or cooling to maintain acceptable indoor levels of comfort even when large areas of glass are used in the design.

Normal clear glass is a very poor insulator – the weakest insulating element in the matrix of materials used in building construction – and so, in recent years, there has been a huge incentive to develop sophisticated glass types which deliver superior thermal insulation performance with excellent appearance from outside and adequate daylight transmission to the building interior.

For fitness of purpose in a typical Middle Eastern environment, the acid-test is how well the glass will assist in maintaining a cool interior when the sun is shining. How does one measure the resistance of a glass type to the transmission of solar energy?

K-Lite high-performance (HP) glass manufactured by Saudi American Glass Factory is designed to cut solar energy transmission to the lowest possible quantity. Two parameters are used to tell the designer how much solar heat will pass through the K-Lite glass which he has selected for his building. These are the Solar Factor and the Shading Coefficient.

The solar factor (SF) is a measure of total energy transmission (TET) of any particular glass. It is expressed as a fraction of the total solar energy striking the glass in standard summer conditions, compared to the amount of energy passing through the glass directly and by re-radiation. Remember that some of the heat is reflected and re-radiated back to the atmosphere.

To make the SF measurement universal and equal, the American Society of Heating, Refrigerating and Air-conditioning Engineers (Ashrae) has created a set of standard summer conditions based on:

- A constant flow of solar energy = 750 w/sq m
- The sun is 30 degrees above the horizon.
- The sun strikes the glass at 90 degrees.

For piece of 3 mm clear float glass, which is the thinnest commercially available clear glass, the SF is 86 per cent which is expressed as a decimal fraction = 0.86. This is the glass with the least thermal resistance. How does one compare the performance of the desired glass type with standard 3 mm clear glass – the benchmark glass?

This is done easily and simply by creating a second parameter known as the shading coefficient (SC). Since 3 mm clear glass has the highest SF (0.86), this glass type is given a shading coefficient of 1.00, the highest number. That is to say SF (0.86) = SC (1.00).

To compare a chosen glass with the benchmark 3 mm clear glass, you take SF÷SC, giving a decimal fraction which is the shading coefficient. In other words, a K-lite high-performance glass type with SC=0.15 gives six and half times more solar protection than 3 mm clear glass.

To maximise protection from the sun, there is no better product than K-Lite HP glass which has solar factors as low as 0.10 and shading coefficients as low as 0.12 (0.10÷0.86 = 0.12). K-Lite HP glass is a sputter-coated solar reflective glass which can be supplied in annealed, tempered or heat-strengthened form. It can be incorporated in insulated double-glazed units and can be laminated using PVB interlayer material.

K-Lite HP glass by Saudi American Glass Factory is the perfect solution for structural silicone curtainwall systems, giving beautiful uniform colour and reflectance, fully meeting the requirements of contemporary architectural fashion for structures which appear to "float" without visible means of support. Thanks to the low shading coefficient of K-Lite HP glass, the building occupants can be fully protected from the scorching sun while enjoying perfect outside visibility and lowest possible cost of staying cool.

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sealed off. These tubes however, are susceptible to damage, leaking, or even their sealing being forgotten. Automated vertical assembly therefore, is far preferable.

Changes in the pressure of the insulating glass space also occur due to heating and cooling of the air inside. The IGU is typically manufactured in a climate-controlled environment in order to achieve maximum reliability for the sealants and desiccant. Exterior glass surface temperatures during summer in the Gulf are typically around 60 deg C in the sun, with inner panes being approximately 35 deg C, for an average rise of about 24 deg. Applying Boyles law ($P_1V_2/T_1 = P_2V_2/T_2$ implies that to equalise pressure, the volume within the IGU would increase by about 8 per cent. Such expansion is manifested by a convex distortion (the pillow appearance) of the glass.

Another cause of air pressure change is altitude. Air pressure changes with altitude according to the Barometric Formula (refer http://230nscl.phy-astr.gsu.edu/hbasa/hframe.html). This can be approximated for altitudes applicable to buildings by multiplying the height in metres by 11.3 to obtain the pressure drop in Pascals. Visual distortion from the ground becomes less apparent the higher you look and the closer you are. However, there is a pressure difference of approximately lkPa at the top of a typical 25-storey building, and it varies linearly with height (this close to the ground). The glass in IGUs will bulge due to the difference in pressure between the inner air space and the ambient pressure outside, according to their height in the building. By way of comparison, lkPa is the force generated by a wind of about 145 kph.

Installation

The final cause, and one of the most avoidable, is local distortion at the edge of the glass at the fastener locations. This can be a function of the fastener spacing or the stiffness of the glazing pressure plate, the torque on the screws, gaskets not properly installed, etc. Also in this category is distortion where the frame is not in plane, but this is infrequent and perhaps the least noticeable.

In summing up, the glass industry should tighten the standards for surface flatness in manufactured glass, or at least offer a higher level for projects in which reducing distortion is considered important. Such a quality improvement would result in the glass manufacturer rejecting more glass, and this would be reflected, so to speak, to some extent in the glass cost.

IGU construction contributes to problems, and while this type of glass is imperative for many typical ‘soft’ reflective coatings (as opposed to pyrolitic coatings), other methods of creating the insulating air space are in use.

For example, one of the premium quality windows in the US, Pe1la, utilises a system where an inner pane, with a small hole in it, is clipped into the frame. The air space is kept dry because it is connected to the conditioned air inside, and the unit can be removed for periodic cleaning if necessary.

Reducing distortion at fastener locations simply requires a willingness on the part of the industry and an awareness on the part of the project management team. The UAE is becoming a leader in the construction of high-rise glass-clad buildings, and it is time to think about the example the country's builders is setting for others.

**The author is owner and president of Thomas Bell-Wright International Consultants, a Dubai-based firm specialising in quality assurance and testing for curtain wall and glazed aluminium.*

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