



Technical Bulletin

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Spontaneous Breakage of Tempered Glass

Spontaneous breakage of tempered glass is immediately noticeable because an initial crack exceeding a critical size (depending on its location within the thickness of the glass) causes complete fracture of the plate, typically into very small particles, approximately cube shaped. Clumps of these small particles tend to stay together, much like a jig-saw puzzle, after breakage unless additional forces are applied. In annealed glass an initial crack may not have a sufficiently large applied load or internal stress to propagate it completely, and so even a relatively large crack may go unnoticed for some time. Some of the possible causes of initial cracking in tempered glass can include: damage from hard body impacts, glass-to-glass contact, especially where edges can bump during installation, weld splatter, or deep scratches, penetrating just into the tensile stress zone. Stresses which can cause initial cracks to slowly grow (static fatigue) include: the locked-in tempering stress; building movement - concrete floor creep etc, which takes up the edge clearance in a frame and causes localized bearing pressure and crushing, especially if the glass and frame sizes were not correct; differential expansion/contraction stresses from stiff adhesives (epoxies) used to glue items to tempered glass; and the expansion of Nickel Sulfide (NiS) inclusions in the central half of the glass thickness.

NiS inclusions are very small, spherical shape, opaque solids, typically 0.1 to 0.5 mm dia (0.005" to 0.020") and which change their crystalline phase (Alpha to Beta) and size long after the tempering process. This Alpha to Beta change makes them expand slightly. When glass is tempered a NiS stone inclusion actually shrinks more than the surrounding glass during the quench cooling. This sudden quench catches the inclusion in its smaller, hot, Alpha phase, not giving it time to make its usual transition to the slightly larger, cold, Beta phase. With time (months or years), the phase change and growth of the inclusion, take place in the cold glass. The changes take place faster if the glass is warmer, such as in insulated spandrel panels exposed to sunlight. At first there is little stress on the surrounding glass while the stone slowly expands to fully occupy the cavity. With further growth in size, as the phase change is completed, the surrounding glass is subjected to an increasing tensile stress. There are many different compositions of a NiS inclusion. The exact composition of a NiS inclusion is a factor in

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determining when the full expansion and possible breakage occur. It can take many months or years, and even then, breakage may not happen at all. Typically, such expansion and the first occurrence of breakage will not happen until at least a year has passed from the date of tempering.

It is now generally known that metallic Nickel (in solid particle form) contamination of the raw materials for glass manufacture can combine with sulfur (probably from the furnace fuel) during melting to form small Nickel Sulfide (NiS) inclusions in clear or tinted glass. Such metallic Nickel inclusions, even though they may be as small as 0.08 mm (0.003") in diameter, may cause spontaneous breakage if the glass is subsequently heat treated. This breakage can occur without any load being applied to the glass, at any time, even five or ten years after the glass has been tempered.

While Pilkington **Optifloat™** Grey and Pilkington **Eclipse Advantage™** Grey solar control reflective low-e glass are made with small amounts of Nickel oxide as one of the tinting ingredients, this material is not in a pure metallic form and has never been seen to cause the formation of NiS inclusions, or to cause spontaneous breakage in heat treated Grey glass.

Pilkington NA Inc. recognized the details of this process and in the early 1980's instituted an extensive quality control program to prevent such contamination. Periodic samples are taken from the raw material of the glass batch and run through high power magnetic, and non-ferrous, separator equipment which removes any metallic materials which may have erroneously entered the batch. The removed material is chemically identified and corrective action with the material supplier is taken if a single particle of Nickel is found.

Most of Pilkington's material suppliers use magnetic separation equipment in their production equipment. The suppliers' plant and equipment are also inspected periodically by Pilkington personnel to insure that Nickel bearing metals are not used in their processing and transporting equipment.

At Pilkington plants every effort is made to detect and eliminate metallic contamination in the glass by passing all the raw materials: batch, sand, and cullet (recycled glass), under ferrous and non-ferrous detection equipment just before it enters the melting furnace.

Automatic on-line inspection of the full-width float ribbon in the last decades has also helped reduce the number of inclusions of all types. However, while a NiS inclusion of say 0.13 mm (0.005") diameter can be large enough to cause breakage in tempered glass it is still too small to be detectable during production by the on-line inspection scanners.

Due to the impossibility of finding such very small inclusions, neither Pilkington NA Inc., nor any other float glass manufacturer, can guarantee the complete absence of NiS inclusions in glass. Good glazing design and engineering practice recognizes this fact and accordingly only specifies the use of tempered glass in locations where the unlikely event of spontaneous breakage will not cause significant problems.

Heat Soaking glass after it has been tempered is a process which, when properly performed, can destructively uncover most NiS inclusions, if any are present. But it is never 100% effective and it does incur the slight risk of some de-tempering of the glass. When properly performed,

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heat soaked tempered glass will still meet the full requirements of ASTM C 1036 and ANSI Z 97.1.

NiS inclusions, though uncommon, can occur in all float glass, from any manufacturer. A paper by Dr. Andreas Kasper of Saint-Gobain, Germany, presented at Glass Processing Days, Finland, in June 2001, stated that he found one break caused by a NiS inclusion in every 8.7 tons of glass during the destructive heat soak tests of samples of glass from 25,000 tons of glass from different production sites. It should be observed that not all of these inclusions would necessarily have caused tempered glass breakage in installed glass.

A paper: "Nickel Sulfide Induced Failure of Glass", 2001, 47 pages, by Centre for Windows and Cladding Technology, University of Bath, England (sponsored by: Ove Arup, Bovis Lend Lease, and others), stated that a NiS stone with the potential to cause spontaneous breakage in FT glass exists once in every 4 to 12 tons of glass, on a global average. This paper also stated that half of any such breakage can be expected in the first 800 days (26 months) or so after tempering.

Heat Strengthening rather than full tempering is often used where additional glass strength compared to the annealed product is required, such as in resisting thermally induced stress in solar control glazing. However, heat strengthened glass does not satisfy code requirements for safety glazing. Spontaneous breakage from NiS inclusions seldom occurs in properly heat strengthened glass, even though it is possible and has been observed.

Pilkington's product brochure has long contained a warning note of such possible breakage. The current Product Guide (available on our website at www.pilkington.com/na , page 6 reads:

"On rare occasions, heat-treated (tempered and sometimes even heat-strengthened) glass can break spontaneously, without any applied load, due to small inclusions that may be present in all float glasses."

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

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