Tempered Glass

DEFINITIONS

In the production of flat glass the molten silica-based mix is cooled slowly under carefully controlled conditions. This annealing procedure removes undesirable stresses from the glass. Cooling occurs in an annealing "lehr"; hence, the glass is termed "annealed" or "ordinary" glass. Annealed glass which has been heated to a temperature near its softening point and forced to cool rapidly under carefully controlled conditions is described as "heat-treated glass." The heat treating process produces highly desirable conditions of induced stress (described below) which result in additional strength, resistance to thermal stress, and impact resistance.

Heat-treated glasses are classified as either fully tempered or heat strengthened. According to Federal Specification DD-G-1403B, fully tempered glass must have a surface compression of 10,000 psi or more or an edge compression of 9,700 psi or more. Heat-strength glass must have a surface compression between 3,500 and 10,000 psi, or an edge compression between 5,500 and 9,700 psi. The fracture characteristics of heat- strengthened glass vary widely from very much like annealed glass near the 3,500 psi level to similar to fully tempered glass at the 10,000 psi level.

HEAT TREATMENT PRINCIPLE

Glass can fracture when its surfaces or edges are placed into tension. Under these conditions inherent surface or edge fissures may propagate into visible cracks.

The basic principle employed in the heat treating process is to create an initial condition of surface and edge compression. This condition is achieved by first heating the glass, then cooling the surfaces rapidly. This leaves the center of glass relatively hot compared to the surfaces. As the center thickens then cools, it forces the surfaces and edges into compression. Wind pressure, missile impact, thermal stresses or other applied loads must first overcome this compression before there is any possibility of fracture.

MANUFACTURING PROCESSES

In the "heat-treatment" process the key procedure is application of a rapid air quench immediately upon withdrawal of hot (approx. 1200 ° F) glass from the "tempering furnace." The immediate and sustained application of an air quench produces the temper. As air direction against hot glass from arrays of fixed, reciprocation or rotating blast nozzles, it is important to extract heat uniformly from both surfaces (uneven heat extraction may produce bow or warp) and to sustain the quench long enough to prevent reheating of the glass surfaces from the still-hot glass core. A quenched condition becomes stable when the glass is reduced to a temperature of approximately 400-600 ° F.

There are two principal manufacturing methods for producing heat-treated glass. One process heat treats the glass in a horizontal position while the second method moves the glass through the furnace in a vertical position with each light of glass held by metal tongs.

STRENGTH

Under wind pressure, tempered glass is approximately four times as strong as annealed glass. It resists breakage by small missiles traveling approximately twice as fast as missiles which break annealed glass. Tempered glass is also able to resist temperature differences (200 ° F - 300 ° F) which would cause annealed glass to crack.

	Annealed Glass	Tempered Glass
Typical Breaking Stress (large light 60 sec. load)	6,000 psi	24,000 psi
Typical Impact Velocity Causing Fracture (1/4" light 5 gm missile, impact normal to surface	30 ft/sec	60 ft/sec

SAFETY

Fully tempered glass is used in many applications because of its safety characteristics. Safety comes from strength and from a unique fracture pattern. Strength, which effectively resists wind pressure and impact, provides safety in many applications. When fully tempered glass breaks the glass fractures into small, relatively harmless fragments. This phenomenon called "dicing," markedly reduces the likelihood of injury to people as there are no jagged edges or sharp shards.

Fully tempered glass is a safety glazing material when manufactured to meet the requirements of the ANSI Z97.1 Standard and Federal Standard CPSC 16 CFR 1201. Federal Standard CPSC 16 CFR 1201, as well as state and local codes, require safety glazing material where the glazing might reasonably be exposed to human impact. This includes doors, tub and shower enclosures, side lights, and certain windows. Applicable building codes should be checked for specific information and requirements.

USES FOR TEMPERED GLASS

Fully tempered glass is used traditionally in place of other glass products in applications requiring increased strength and reduced likelihood of injury in the event of breakage. The building industry, motor vehicle industry and certain manufacturing industries find tempered glass is effective and economical in a wide range of applications.

Fully tempered glass can satisfy federal, state and local building code requirements for safety glazing in such applications as doors, side lights, shower and tub enclosure, and interior partitions. It is also used in storm doors, patio-door assemblies, and escalator and stairway balustrades. As a glazing product it is used in windows and in spandrel areas (for wind pressure, small missile impact and thermal stress resistance). Special building applications include sloped glazing, racquetball courts, skylights (see below), and solar panels. Any conditions or requirements imposed in the applicable safety glazing laws and building codes limiting such special uses should be determined prior to glazing.

The domestic motor vehicle industry employs tempered glass as side and rear windows in automobiles, trucks, and multi-purpose vehicles. Manufacturing industries use tempered glass in refrigerators, furniture, ovens, shelving, and fireplace screens.

Tempered glass should not be used where building codes require wired glass for fire-spread resistance. Tempered glass should not be used, alone, where the objective is to provide security against forced entry or bullet passage. Combinations of annealed and tempered glass can be effective barriers against forced entry and bullet impact, if properly designed and constructed. When using tempered glass in fireplace screens, provisions must be made for expansion and edge insulation.

TEMPERED GLASS IN SLOPED GLAZING AND SKYLIGHTS

Because of its high resistance to thermal stresses and small missile impact, tempered glass is used in skylights and sloped glazing. On rare occasions when tempered glass in these applications fails, it may fail completely from the opening, individual fragments from tempered glass are relatively small and harmless. A number of these fragments may be loosely joined and fall in this manner.

Such pieces do not have the sharp edges normally associated with broken glass but may have significant weight. Some building codes may require the use of screens under skylights. The use of screens may also be dictated by considering the risk of breakage and the resulting consequences.

HANDLING AND INSTALLATION

Tempered glass should receive the same care as annealed glass. Unfortunately, familiarity with the greatly improved strength of tempered glass may mislead people to exert less care in handling it. Careless handling and improper installation sometimes produce edge damage. Delayed breakage can ensue when edge-damaged tempered glass is subjected to a moderate thermal of mechanical stress. Full penetration of the compression layer will likely produce instantaneous total fragmentation of tempered glass. Hence, tempered glass cannot be cut or modified following heat treatment.

IMPERFECTIONS

Inclusions in glass originate from impurities in th batch or cullet, or are combined from furnace refectories. Common forms of inclusions include aluminous stones, iron stones, and silicon. Nickel sulfide stones are uncommon, microscopic defects in glass, and may cause breakage. Delayed breakage may occur when a nickel sulfide stone is present near the center of the glass thickness.

The tempering process rarely introduces imperfections into glass. The basic glass may contain bubbles, vents, chips, and inclusions which, if accepted or not revealed by inspection before tempering can cause breakage in the initial heating or final quench operations. If inclusions are not eliminated by self destruction during the tempering process, in rare cases they may lead to failure at a later time.

VISUAL APPEARANCE

Tempered glass possesses the basic optical qualities of annealed glass. The induced stress condition sometimes produces a slight bow in tempered glass lights. Tempered glass that has been manufactured in a vertical tempering oven contains small surface depressions resembling dimples along one edge. These marks are caused by the pointed metal tongs which support the glass during its passage through the oven. Glass which is passed horizontally through an oven may contain a very slight surface wave caused by contact with the rollers. The waviness can sometimes be detected when viewing reflected images from a large distance. Finally, the air quench nozzles discharge air in a fixed, reciprocating or rotating motion. The area of air quench can be seen through polarized glass as arrays of iridescent spots or lines. Under some lighting conditions these patterns can be seen in ordinary light.