Safety Glazing, by Douglas Hansen

Glass in some form or another has been used since thedawn of civilization. It appears naturally as obsidian, and the first man-made glass objects date from 3500BC. The Romans used a semi-clear glass in windows beginning around 100 BC, and little progress was made in glazing technology for the next 1200 years. The mass-production technology of modern glass is relatively new, post WWII. The subject of glazing has many aspects, including heat emissive properties, light transmission, insulation(dual or triple pane), leak prevention, wind-resistance, acoustics, sealants, and architectural considerations. The scope of this article is safety glazing, and the areas where inspectors look at the hazards posed by glazing.

The Danger

When a person accidentally impacts glass, there are two immediate dangers. The first is from lacerations due to the large shards that might slice into the person. There have been numerous instances of persons who have died from injuries such as a severed femoral artery. Unless pressure is brought to bear immediately on such a wound, the victim can bleed to death in as little as five minutes. The second danger is from the "rebound" affect. When someone strikes a piece of glass, typically his progress is stopped and impact causes him to bounce back, but by that time the glass is broken. During that rebound, the person is pulling away from the sharp edges of the glass, and the result can be deep lacerations that tear off large flaps of skin.

Causes of Impact

Most accidents with glass are due to one or more of three contributing factors:
1. Failure to see the glass
2. Slips and falls—even knowing the glass was there, and
3. Intentional breakage.

The rules in building codes and federal standards typically are based on one or more of these factors. Historically, the greatest number of injury accidents has been from shower doors or patio doors (figure 1).

Figure 1 – Accidental Impact with Glass

From Courtroom to Codes

Building codes were silent on the subject of safety glazing until the 1960s. Glass manufacturers found themselves the subject of numerous lawsuits, and they recognized the need for uniform standards for the industry. The National Safety Council formed a task group with the National Glazing Association, and found an average of 320,000 injuries per year from people impacting glass in doors and windows. The group worked to form a standard for impact resistance of glass, and, in 1966, it was accepted as a National Standard and given the designation ANSI Z97.1. From 1968 to 1973, the Glazing Industry Code Committee attempted to lobby states directly for adoption of this standard as part of state building codes for glazing in hazardous locations—those that are subject to human impact. They achieved a small measure of success with some form of adoption in 32 of 50 states, though in many cases the standard only applied to commercial construction. That did not meet the needs of the glazing industry, as they were finding the greatest number of injuries occurring in residential applications, particularly patio doors and shower enclosures. At the same time, the manufacturers remained relatively ignorant of the building code adoption process, which was further complicated by fragmentation among various regional code authoring agencies.

In 1972, the United States congress enacted the Consumer Product Safety Act, which created a new government agency, the Consumer Product Safety Commission (CPSC). When it opened its (glass) doors in 1973, one of its first tasks was to address the hazards of glass. Though armed with the ANSI standard, the commission went beyond it, and developed a two-tiered standard. A person will typically bear more of his or her body weight in impact with a large piece of glass than he or she would with a smaller piece. The CPSC standards resulted in Class I glass rated at 150 foot pounds of impact, and Class II rated at 400 pounds. These became part of CPSC 16 CFR 1201, and they became law on July 6, 1977. These designations may sound familiar, as they are seen on the identifying "bug" used in tempered glazing today (*see Figure 2*).

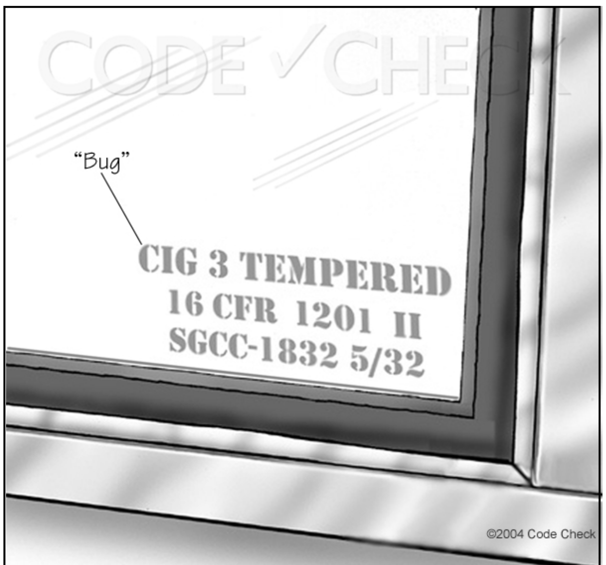

Figure 2 – Safety Glazing "Bug"

The ANSI standard has since changed, and now includes three impact categories. Class A & B are similar to CPSC's Category I & II, and class C has the 100-pound rating. This voluntary standard did not require the classification to be marked on the glass until the 2004 edition.

Both the ANSI standard and the CPSC rules provided guidelines for building codes, whose job it remained to identify the specific areas where safety glazing is required.

Historically, building codes are developed from the ground up. Proposals are initiated by individual building officials or groups of building officials, and the proposals work their way up through committees to an eventual vote by the entire conference of the code-making body. When safety glazing codes were first developed, there were three major code-making organizations, ICBO, BOCA, and SBCCI. ICBO's Uniform Building Code 1961 edition was the first to require safety glazing for shower doors. Even before the eventual merger of the old territorial codes into the ICC, they became fairly consistent in the last few years prior to the merger, in part by following the federal guidelines.

Test Procedures

For the CPSC test, a piece of glass is secured to a vertical frame, and a punching bag filled to 100 pounds with lead shot is suspended a half inch in front of the glass. For Class I glass, the bag is lifted away and released at a point where its vertical drop is 18 inches. For Class II, the test requires a vertical drop of 4 feet. The glass must either not break, or break into such small shards that the 10 largest do not add up to 10 square inches. In the case of laminated glass, a hole punched in the glass must not allow passage of a 3-inch steel ball rolled over the glass. Further details on the test procedure are available in the Code of Federal Regulations on the Web. See the links at the end of this article. They were also specified in UBC Standard 24-2.

Standards of Practice

ASHI requires a home inspection to include items that are unsafe in the opinion of the inspector. Unsafe is defined as "A condition in a readily accessible, installed system or component that is judged to be a significant risk of bodily injury during normal, day-to-day use; the risk may be due to damage, deterioration, improper installation, or a change in accepted residential construction standards."

When it comes to issues like safety glazing, there is no “grandfathering” of existing non-conforming conditions. Just as the glass isn’t going to stop and read the code before it decides to cut you, we, as inspectors, can’t be concerned with the age of the property in deciding whether to report this safety condition. Several state standards adopt specific language requiring inspection for safety glazing where appropriate.

Inspectors are often asked whether a specific glass installation met code at the time of construction, and if replacing the glass would be considered a necessary repair or an upgraded safety enhancement. The answer to that question is a real estate negotiation, not an issue for the inspector. The inspector’s job is to conform to ASHI’s reporting requirements and definition of safety, and to make a recommendation to replace non-safety glass in hazardous locations. Likewise, Realtors® or landlords probably would not be putting themselves in a good spot if they fought to keep a dangerous situation and later saw it result in a serious injury. The inspector’s role is to point out the defect, not to decide who fixes it. Most things that we now report as defects in safety glazing conformed to code at the time of construction. The person with greatest liability would be the installer if they violated the standards of the glazing industry. The glazing industry often will be following a newer and more restrictive code even before the local jurisdiction has adopted it.

Types of Glazing

Before looking at the specific locations that have been deemed hazardous, we shall review the different types of glass. Annealed glass (float glass) is the ordinary glass that is cut into “stock sheets” for packaging and shipping. It can be cut again, and it possesses none of the properties of safety glazing. It breaks into sharp shards. A heavier form of this glass is plate glass that is formed between high pressure rollers, and in some thicknesses obtains relatively high strength, though it is not safety glass.

Heat Strengthened Glass (H.S. Glass) is annealed glass that goes through a heating and cooling process designed to double its strength in comparison to ordinary annealed glass. It is heat resistant, and may not be cut after manufacture. It is not a safety glazing product, as it meets neither the ANSI Z97.1 or the CPSC standards.

Laminated glass has two separate pieces of annealed, heat-strengthened, or tempered glass sandwiched around a layer of clear polyvinyl butaryl (PVB). The layers are bonded under high pressure. In the United States, it is used in car windshields. It is a safety glass product. One side can shatter from impact without the other side shattering, and when the glass shatters it does not delaminate into shards. Laminated glass is often used for frameless railings (*Figure 3*).

Figure 3 – Laminated Glass Railing

Tempered glass (used in the rest of the car windows) is created during manufacture by rapidly cooling the outer surfaces of a piece of glass while the inner portion, sandwiched between the outer layers, remains viscous. After final cooling, the inner portion of the glass is in tension while the surfaces are in compression. The result is a piece of glass that is four times more resistant to impact than annealed glass. When tempered glass breaks, it fractures perpendicular to the plane of the surface, rather than parallel to it, resulting in harmless small cubes that are less likely to cause significant injury. All glass is vulnerable to breakage from impact at the edges, and tempered glass is even more vulnerable in this regard; scratch the edge with a file and the entire piece might shatter. Because of this characteristic, tempered glass must be cut to size before the tempering process. Tempered glass has characteristic bows and warps due to the tempering process.

Approved plastics that meet the ANSI Z97.1 Standard are another form of safety glazing. Limitations on its acceptable use arise from fire resistance ratings. In garages, inspectors may find that original glass panels in exterior passage doors have been replaced with plastic. While it may provide safety, a disadvantage of plastic is that it easily becomes permanently scratched. Plastic is often used in skylights.

The Wired Glass Dilemma

Though wired glass has the advantage of preventing large shards, numerous injuries have occurred due to the rebound effect. Wired glass has only half the strength of ordinary annealed glass due to internal stresses from differing rates of contraction on cooling. It was once used as a form of safety glass, but that application has been abandoned since approximately 1970. The only prescribed use since then is for skylights and for windows in areas requiring fire separation.

Wired glass is commonly used in “vision panes” of swinging doors to allow someone to see persons on the other side. This violates the original CPSC standard, but was allowed until quite recently. When the choice has been between glass with a fire rating, or glass with a proper safety rating, the fire rating has won out.

Figure 4 – Glass vision pane

Greg Abel, from the Advocates for Safe Glass, came to this issue in a personal way. His son was injured by a wired glass lite at his school basketball court (*see Figure 4*). The result was an injury that included severed nerves and tendons and permanent damage. Sadly, this story is not unusual; approximately 2,500 such injuries occur each year in elementary schools alone. Mr. Abel founded a nonprofit organization to raise awareness of this issue and to lobby for enforcement of requirements for impact resistance. Why did we allow glass that does not meet impact resistance standards in doors and other public areas? A long protracted lawsuit from the wired glass manufacturers (all based offshore) tied up the CPSC and resulted in exceptions that remained in the building codes until 2006.

Fortunately, Mr. Abel’s long efforts on behalf of public safety eventually paid off with successful amendments to the 2006 codes, and wired glass is no longer allowed in locations subject to impact.

There are alternative products that provide both impact resistance and fire resistance. A British company has provided a product known as “Pyro-Shield” for fire-rated applications. Ordinary Pyro-Shield fails the CPSC impact test, but another product, Pyro-Shield “Plus” (Pyro-Shield Safety) does meet the test and is available. Other manufacturers also have products that are both fire and safety rated, including Inter-Edge, Safe-T (O’Keefe), Vetrotech and others. These alternative products do have a safety glazing bug in the glass, and Warnock-Hersey test labs has an evaluation and label for glass that is both fire rated and tempered.

Just because a piece of wired glass has a “bug” on it, do not assume it is safety glass. The vision pane in Figure 4 is obviously in a location subject to human impact, but the “bug” stated that the glass was evaluated by UL only for fire-resistance, and not to any other standard.

Locations Subject to Human Impact
What then, is a hazardous location “subject to human impact?” The building code (2006 IRC) provides us with definitions. These include areas where a person might be aware of the glass yet still slip and fall, such as a shower or walkway. Another hazard is glass that people might not be aware of, such as sliding doors where a person could think the door was open and walk (or run) straight into a piece of glass. Glass that is tempting to break is also a hazardous location. An example would be glass in or near doors where a person might break the glass to reach the doorknob.

Old sliding doors are considered so unsafe that some municipalities, such as Los Angeles, require replacement or protection with glazing film upon sale of the property. Courts have upheld liability claims against landlords for injuries caused by unsafe glass in shower enclosures. When inspecting an older apartment, you might save the tenants from injury, and the landlord from an expensive lawsuit, by recommending older glass be replaced with safety glass.

The term “hazardous locations” is used in building codes, and in this case the term only pertains to glazing. In other codes, such as the NEC, the term is used for areas with explosive materials. In the 2006 IRC, section R308.4 lists these hazardous locations:

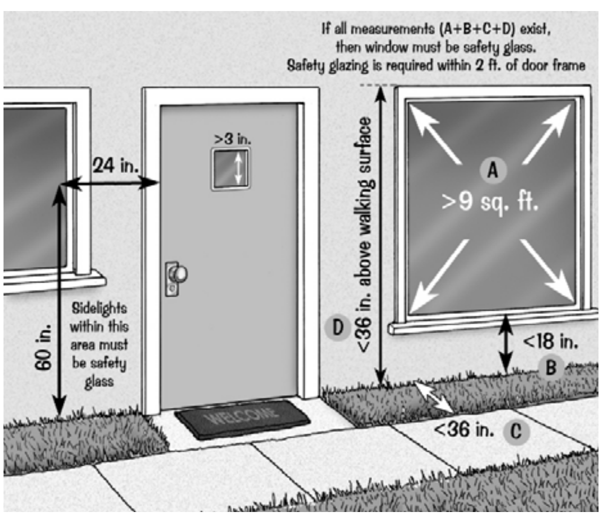

Figure 5 – Windows, Doors & Sidelites

1. Swinging doors. Any glass pane in a door is required to be safety glass, with exceptions for jalousie windows, lites so small that a 3-inch sphere cannot pass through them (*see Figure 5*), and for art glass (etched, decorative, or beveled glass).

2. Sliding doors, including the fixed panes, and bifold closet doors, with no exceptions.

3. All glazing in storm doors.

4. Glazing in unframed swinging doors (these will typically be laminated glass).

5. Glazing in doors and enclosures for showers, tubs, saunas, and whirlpools, as well as windows in a wall enclosing such an area if the bottom edge of the window is less than 60 inches above a standing surface, with no exceptions (*see Figure 6*).


Figure 6 – Shower and Tub Enclosures
In this example, the shower enclosure at the left contained tempered safety glass, and the glass blocks at the end of the tub are exempt. The leaded glass next to the tub is not allowed; any windows in that area must be safety glass.

6. Sidelites where any part of the lite is within 24 inches horizontally of the door frame and less than 60 inches above the floor or walking surface (*see Figure 5*). There is an exception for art glass, or for sidelites near a closet door if the closet is less than 3 feet deep. A new (2006) exception allows sidelites that are perpendicular to the door frame to not be safety glass, except for a sidelite that is on the wall toward which the door swings. The reason for still requiring

that lite to be safety glass is that someone could open the door from the opposite side and a person could be pushed toward the sidelite. This last exception is only for one- and two-family dwellings, not commercial buildings.

7. Large windows that meet all four of the following conditions are a “walk-through” hazard (*see Figure 5*):

1. Greater than 9 square feet, and
2. Lower edge less than 18 inches from the floor, and
3. Upper edge more than 36 inches from the floor, and
4. A walking surface within 36 inches horizontally of the window.

For these windows, there are exceptions for art glass, as well as an exception when a minimum 1 1/2 in. protective bar is installed within 2 inches of 36 inches above the floor, and the bar can withstand a horizontal load of 50 pounds per foot. The reason for these windows to be safety glass is because they can be mistaken for a door opening. Many window manufacturers supply windows that have a muntin at the 18 inch height to divide the window into two lites, neither of which are then required to be safety glass.

8. Glazing in railings regardless of height above a walking surface. These are usually laminated glass.

9. Glazing with any part less than 60 inches above a walking surface and within 60 inches horizontally of a pool or spa, be it indoors or outdoors. In a multi-lite assembly, this rule applies to all the lites if any one of them is within 60 inches of the pool.

10. Glazing that is less than 60 inches above the walking surface and within 3 feet horizontally of stairways, landings, or within 5 feet of the bottom tread of a stairway. An exception allows the glass to be within 18 inches horizontally if protected by a guardrail or handrail. A new exception also allows this horizontal distance to be zero if the area below the glass, 34 to 38 inches above the walking surface, is solid and the top of the solid surface can sustain a horizontal force of 50 pounds per lineal foot. This last exception is only in the IRC and does not apply to commercial buildings.

Jalousie windows are exempt. Their edges must be smooth, and they must be at least 3/16 inches thick. Finally, there is an overall exemption for glass blocks (figure 6) when they are properly installed in accordance with the rules for that form of masonry. Mirrors, including those on wardrobe doors, are exempt if they are on a solid surface that provides a continuous backing support. If a wardrobe door mirror breaks, the glass shards are supposed to remain adhered to the backing, and not pose a hazard.

Skylights

Skylights are not a “location subject to human impact,” but precautions must be taken to assure occupant safety if the glass breaks. Glass in skylights or sloped glazing (more than 15 degrees off vertical) must be wired, plastic, laminated, heat-strengthened, or fully tempered. Screens are required beneath heat-strengthened or tempered glass panes, except for tempered glass less than 16 square feet and the highest point not more than 12 feet above a walking surface, or 10 feet if the glass is sloped 30 degrees or less from vertical.

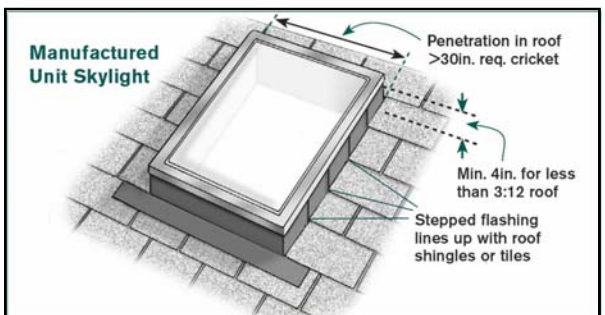

Figure 7 – Manufactured Unit Skylight

Skylight curbs must be at least 4 inches above the plane of the roof if the roof is less than a 25 percent slope (3:12) unless otherwise specified in the manufacturers instructions. This height helps to construct proper flashings, and also makes the skylight more visible to a firefighter. A change in the IRC (section R905.2.8.3) now requires a cricket or saddle for all roof penetrations wider than 30 inches (figure 7). The old rule was only for chimneys, and the new rule includes skylights. This will have the effect of forcing the framing to be deeper to allow for the height of the cricket.

Identifying Safety Glass

An etched label as in Figure 2 is required for tempered safety glass, and has been since the first mention of tempered glass in the codes. A full label is required on at least one lite of multi-pane assemblies, and the others in the assembly can be marked with only the "16 CFR 1201" designation. A new rule in 2006 no longer requires the thickness of the glass to be included in the label.

Another exemption for labeling is provided for tempered spandrel glass, which is seldom found in residential applications. It is a type of opaque glass that is heat-strengthened by fusing a ceramic coating to the surface, and it is used for commercial curtain walls. An etched label could have a different coefficient of expansion and cause the glass to break, so tempered spandrel glass is allowed to have a removable paper label.

Laminated glass is sometimes labeled, though most codes do not require it. Laminated glass can be identified by its reflection — if you hold your hand to it, you will see multiple reflections (*see Figure 8*). With a little practice, these are readily distinguishable from the two reflections you might see from the inner and outer surfaces of a piece of non-laminated glass.

Figure 8 – Identifying Laminated Glass

Inspectors are often baffled by glass that has a frame obscuring the label, or in the case of shower doors, a soap or hardwater residue obscuring the glass. It is possible to verify that tempered glass is present by using a pair of polarized light lenses. Normally, if you hold two such lenses over your flashlight, and rotate the lenses to where their polarities are at 90 degrees to each other, all light will be blocked. If you do this with a pane of tempered glass between them, distinctive black lines will appear as you rotate the lenses toward total blackness (*see Figure 9*).

Figure 9 – Testing with polarized light lenses

Many owners and architects find the identifying bugs to be unsightly. Once in a while, building departments will allow omission on multi-lite doors. Such installations might be for a historical building (*see Figures 10 & 11*), where a door had custom-made pieces of tempered glass installed without a bug on them. Though the building code sections on glazing have no provision for omitting the bug, building departments can allow it through the administrative provisions for "Alternate Materials and Methods." In such cases, there must be written documentation on file with the building department.

Figure 10 – Historic Door

Figure 11 – Removable stickers that were allowed in lieu of permanent etched label

Alternatives to Replacement

Thousands of houses built in the 50s through the 70s have large floor-to-ceiling windows of ordinary glass, or have patio doors that are not safety glass. In lieu of replacement, it is possible to strengthen these doors and windows with products such as safety film products such as "Scotchshield" from 3M (figure 12). Applied properly, the material is durable, effective, and not noticeable when properly installed. Since it is a field-applied product, it does not meet the CPSC standard, though it does satisfy the requirements of jurisdictions such as Los Angeles. Inspectors can generally tell if the film has been applied because there will be a slight gap at the edges of the glass.

Figure 12 - 3M™ Scotchshield™ Ultra Safety and Security Window Film

Acknowledgments and resources Thanks to Jim Katen for his editorial assistance. Special thanks to Greg Abel for proving that a committed individual can make a difference; he took on the established interests and won. We will never know how many people have been spared a devastating injury thanks to his efforts.

The Advocates for Safe Glass:
www.safeglass.org

The Source (excellent, though slightly dated, book based on the 1997 UBC): California Glass Association, PO Box 2550, Placerville, CA 95667-2550.

Safety Glazing Certification Council:
www.sgcc.org

Glass Association of North America:
www.glasswebsite.com

Federal law:
http://www.access.gpo.gov/nara/cfr/waisidx_03/16cfr1201_03.html

Glazing industry code committee:
www.glazingcodes.org

Douglas Hansen is a technical writer and retired home inspector. He is the principle author of the Code Check series of field guides to building codes.