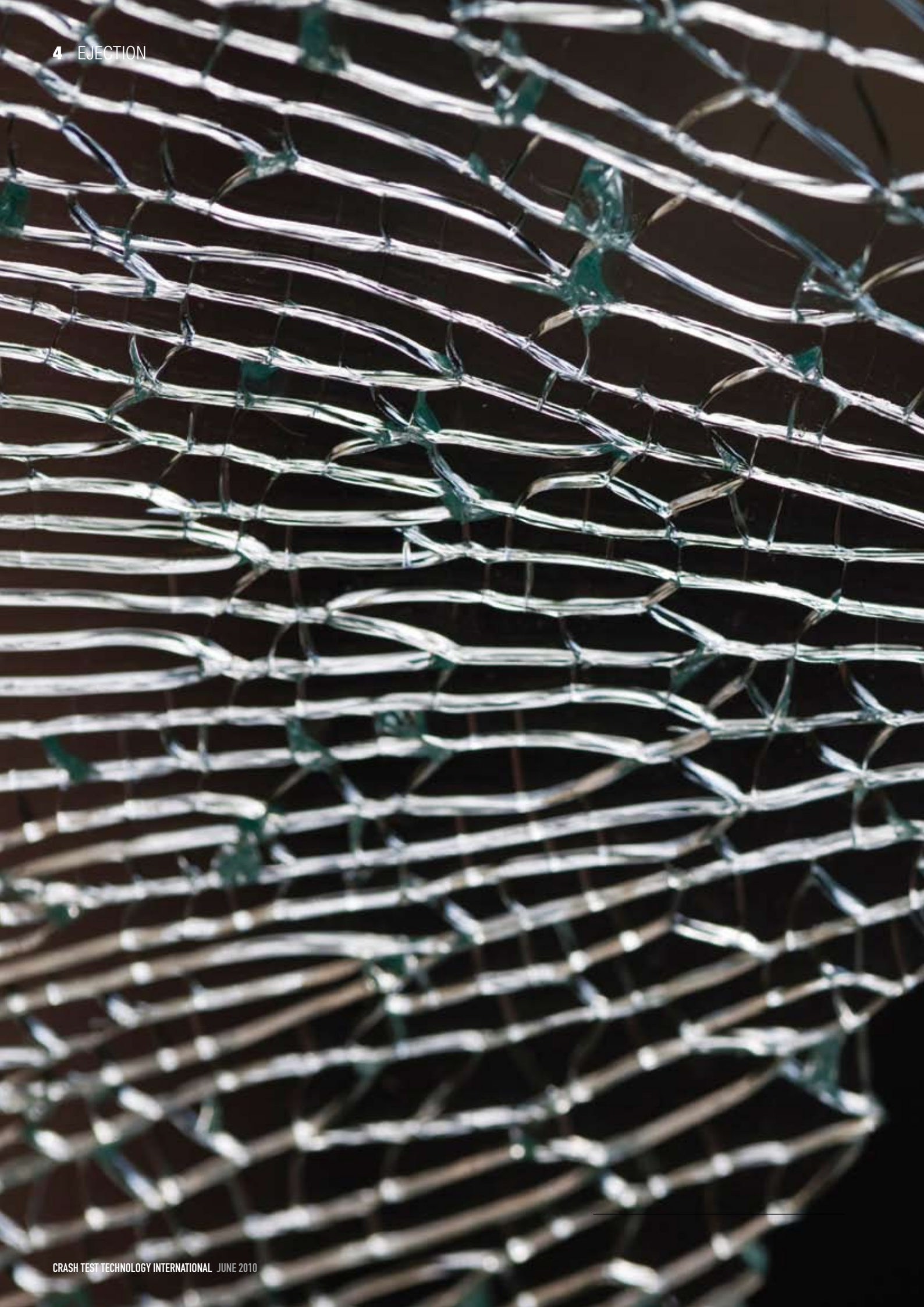

A shattering saga

Byron Bloch studies the latest crash test evidence and discovers how one simple change to side window glazing in vehicles can greatly improve the overall safety of passengers in rollover accidents

■ In side impact and rollover accidents, it is imperative that occupants are kept safely within the protective structures of the vehicle. It is critical that seat-belted occupants are not partially ejected beyond the periphery of the vehicle and its side window glass. It is also critical that all unbelted occupants be prevented from being partially or fully ejected.

The latest NHTSA data shows that 35% of all vehicle fatalities in the USA occur in rollovers, and about half of those occur when the occupants are fully ejected. Even for seat-belted occupants, severe to fatal injuries still occur when the person is partially ejected through the adjacent window opening after the glass has shattered. There is clearly a major problem with the window glazing – and that applies predominantly to side windows, but also to rear hatch windows and sun roofs.

The proposed United States Federal Motor Vehicle Safety Standard FMVSS 226, currently in the final rule-making process, establishes a new safety standard with the intent to reduce the partial and complete ejection of vehicle occupants through side windows in crashes, particularly rollovers. This new standard would apply to the side windows next to the first three rows of seats in motor vehicles with a gross vehicle weight rating (GVWR) of 4,536kg or less. Compliance will be phased into production vehicles, for an increasing portion of each auto maker's fleet, beginning with 20% in September 2014, to 100% by September 2017.

NHTSA anticipates that vehicle manufacturers would meet the standard by using upgraded designs of side-curtain airbags and possibly supplementing them with enhanced protective glazing (EPG),

Below: The upper photo shows the dummy's head smashing completely through the tempered glass, en route to being partially or completely ejected from the vehicle in a side impact or rollover accident. The bottom photo shows the side window of laminated glass serving as a 'life net' to keep the dummy's head and body from partial or complete ejection
Right: A child test dummy is ejected outward through the large side window opening, when the tempered glass easily shatters upon impact by the occupant in a side impact or rollover accident. This is remarkably demonstrative of what happened in Case A (see page 8), in which a young girl was ejected out onto the road and severely injured

such as laminated sandwich designs made up of three layers – glass-plastic-glass. The laminated glass would provide further support for the inflated side-curtain airbags and would also serve as a protective 'life net' ensuring that no occupants are partially or completely ejected.

Side-curtain airbags would probably be made larger to cover more area of the window opening, and would stay inflated for an extended time period (e.g. about six to eight seconds) to ensure continuous protection as the vehicle tumbled multiple times in rollover accidents. Inertial sensors would prompt side airbag inflation when the vehicle was initiating a lateral rollover sequence, based upon tipping angle and velocity through a prescribed arc. In addition, the side-curtain airbags would be securely tethered to minimize any push-out during the FMVSS testing, dynamic rollover testing, or in actual side-impact and rollover accidents.

The NHTSA proposed testing procedure uses a 40lb (18kg) head impactor, which theoretically represents the head of a 50-percentile adult male, striking the target side window at sequential impact speeds of 15mph, followed by a second impact at 10mph. This quasi-dynamic test is much too minimal and unrealistic compared with the impact forces and directions that occur in real-world rollover accidents.

Tempered side window glass has a propensity to shatter in side impact and rollover accidents, or when impacted by the occupant's body. The failure of the thin tempered glass to stay intact thus allows the occupant's head, arm, upper torso or whole body to flail outward or be ejected from the vehicle. The occupant could thereby incur very severe to fatal injuries that would otherwise not occur.

In contrast, the safer alternative of laminated glass – also known as 'advanced glazing' – enables the glass to stay essentially intact during a collision accident. Therefore, it can serve as a safety net, or 'life net', to help prevent the occupant's partial ejection or complete ejection from the vehicle. As mentioned previously, the laminated glass typically consists of a sandwich or layered construction. The outer layer is glass, the middle layer is high-penetration-resistant (HPR) plastic, and the inner layer is glass. This glass-plastic-glass sandwich or layered construction is very similar to the typical laminated windshield that's been standard in virtually all motor vehicles since the 1950s.

In the figures above, note how the dummy's head smashes into and is ejected through the tempered glass, but note the alternative laminated side window glass, which stays intact enough to serve as a life net and keep the test dummy safely within the vehicle. By staying intact, the laminated glass also helps contribute its support to help prevent the roof from buckling downward, as yet another safety advantage.

It is well known that side window glass can and does help support the roof in rollover accidents. Thus, if the side window glass stays intact in a rollover accident, it can help keep the roof more upright and less likely to buckle and crush downward into the passenger compartment survival space. Therefore, incentives that would encourage the adoption of stronger laminated side window glass should be encouraged.

About the author

Byron Bloch has been a US auto safety expert in design and crashworthiness for about 40 years, advocating the adoption of airbags, fuel tanks forward-of-axle, integrated seats, stronger roofs for rollover protection, truck under-ride guards, and other crashworthiness technologies. He inspects accident vehicles, lectures, writes, appears on TV, testifies in court on behalf of severely injured crash victims, demonstrates exemplar designs that are safer, and produces documentaries analyzing car crash accidents and vehicle safety. His website is www.AutoSafetyExpert.com

A warning from the past

DuPont, a major manufacturer of automotive glass, issued a detailed technical report in 1957, entitled *DuPont Research on the Safety Performance of Tempered Glass.*

In this report, DuPont warned about shifting from laminated glass side windows to tempered glass: "The automotive industry is currently showing great interest in substituting tempered glass for laminated glass in the side windows of cars in order to reduce cost. We, and others, familiar with the characteristics of both tempered and laminated glass, consider such a move to be an unwarranted compromise with safety.

"When broken, either by impact or striking a hard object in a crash situation, tempered glass falls out and does nothing to retain passengers inside the vehicle. Laminated glass, even though completely shattered, continues to effectively keep passengers within the relative safety of the car's interior."

Left: Case B. This accident occurred when a Chevy Tahoe SUV was impacted and went out of control, and rolled over onto the driver's side. The woman driver was wearing her lap-and-shoulder seatbelt but, when the driver's door window glass shattered out during the rollover, she was partially ejected and impacted her head onto the road. This animation shows her ejection path through the window opening

"Instrumentation on the dummies would record multi-axis forces generated during the rollover sequence"

The proposed FMVSS 226 does not include any dynamic testing of the vehicle to validate that the occupants would be safely contained in a rollover accident.

What is needed instead is a dynamic rollover test, such as the lateral dolly rollover test described in FMVSS 208, so that the total system is evaluated. This includes injury criteria for the occupants and the evaluation of the roof structure,

the door structure, the door latches, the window glazing, the window retention, the seatbelt, the side torso airbag, the side-curtain airbag, interior surfaces and edges, and other factors that may increase or mitigate injury severity.

The entire vehicle would be tested as to whether or not it performs safely in preventing and reducing injury to the occupant's head, neck and torso. Instrumentation on the dummies would record the levels of multi-axis forces generated during the rollover sequence. I believe the compliance rollover test should be initially conducted at 40mph, then (after four years) elevated to 50mph, then later to 60mph.

European auto makers (VW, Audi, Mercedes, BMW, Peugeot, Volvo and Saab) have been conducting such dynamic rollover tests since the mid-1970s. Their vehicles

Left: Case A. In this Chevy Suburban SUV, a young girl was seated in the middle row seat, wearing her seatbelt. In the collision, the seatbelt buckle released and she was ejected out through the side window when the tempered glass shattered. The arrow shows glass particles embedded within the rubber molding. Below: IIHS side-impact test of a 2008 Chevrolet Malibu. Note that the laminated forward side glass stays intact, while the tempered rearward side glass shattered completely out.

Complete ejection: Case A

Bethany, aged 11, was seat-belted on the second-row seat of a Chevy Suburban SUV. In a moderate collision, the seatbelt came unbuckled and she was ejected through the adjacent large side window opening as the tempered glass easily shattered. Bethany impacted her head on the road, incurring severe trauma to her face, skull and brain. If that large side window had been laminated glass, it would have stayed intact and served as a life net to prevent her from being ejected and severely injured. See figure above.

Partial ejection: Case B

Rhonda, a middle-aged woman, was driving her Chevy Tahoe SUV and was wearing her seatbelt. When struck in the rear corner by another car, the Tahoe SUV went out of control and rolled over. During the rollover sequence, the driver's side window's tempered glass shattered, causing Rhonda to be partially ejected and suffer massive, fatal head trauma. If the driver's side window glass had instead been of laminated glass, it would have stayed intact and served as a life net to prevent her from being partially ejected and killed.

GM's rollover tests in the 50s

General Motors conducted dynamic rollover tests at 50mph (80km/h) in the mid-1950s to show the strength of the roof structure of its production cars, which were also equipped with laminated side window glass.

Now, some 60 years later, US safety standards still do not require any dynamic rollover tests to demonstrate roof strength and side window glass integrity in rollovers. This must change if we are to ever get close to achieving the level of zero deaths in rollover accidents.

perform notably safer in these rollover tests and in real-world accidents compared with US and Japanese vehicles that have not been subjected to such dynamic lateral rollover testing during their development and validation phases.

Furthermore, NHTSA itself conducted similar dynamic rollover tests back in the early 1970s and found that such a test procedure was valid and sufficiently repeatable. The merits of testing to assess the entire vehicle performance, including data on forces experienced by the test dummies, clearly outweighs the criticism that it does not precisely roll the identical way in a series of such tests. But then again, this would show what does in fact happen in real-world rollover accidents.

While NHTSA requires dynamic tests for front impact, side impact and rear impact, there is still no dynamic rollover test. And now, after over 40 years of ignoring occupant ejection mitigation via windows, NHTSA has come up with a totally unrealistic headform impactor test. NHTSA tries to rationalize this minimalist test by boldly stating, "The test has been carefully designed to represent the dynamic rollover event."

However, it appears instead that the FMVSS 226 compliance test has been carefully crafted to require only very minimal performance so that virtually any side window with a side-curtain airbag can meet that requirement.

The proposed FMVSS 226 for ejection mitigation is only a very minimal and unrealistic test when compared with what happens in real-world rollover accidents. Auto makers should not settle for designing

"Automakers must treat the vehicle in total… and make sure their development process includes dynamic rollover testing"

and testing their vehicles and side window glass and side-curtain airbags simply to comply with, or even moderately exceed, such minimum requirements. Auto makers instead must treat the vehicle in total, including roof structure, seatbelts, side-curtain airbags, interior padding, side window glass, door structure and door latches, and make sure their development process includes dynamic rollover testing at least at 50mph, or preferably higher.

It is important to encourage the adoption of laminated side window glass and also improved side-curtain airbags that stay inflated longer. But we must also ensure that doors will stay shut, that stronger roofs won't buckle and crush down, that seatbelts will tighten and that interior surfaces are padded, so that all occupants are better protected during side impacts and rollover accidents.

It is also important to conduct dynamic lateral rollover tests at 50mph-plus to ensure that all production systems perform safely. By doing so, the lethality of occupant ejection in side impacts and rollovers would be greatly minimized, and we would get closer to the compassionate vision of zero fatalities that is advocated worldwide. ■