

mirror is both distorted and smaller than that of the same object viewed in a flat mirror. Therefore, such an object appears farther away and could be less recognizable when viewed in a convex mirror. Additionally, if the object were approaching or receding, its rate of change in position relative to other vehicles and its speed are more difficult to judge as well. For example, a driver who is not familiar with using a convex mirror on the passenger side may determine that it is safe to change lanes to the right, not realizing that a vehicle to the right rear is too close for the maneuver to be completed safely. This is why convex mirrors have been permitted only in conjunction with flat interior mirrors. The flat interior mirror provides the correct depth and speed perception, whereas the convex mirror achieves greater field of view, but cannot give precise depth and speed perception. Even if the interior mirror does not meet the field of view requirements in the standard, it is still available for speed and distance judgment of vehicles that are detected in the right convex mirror, if they are also visible in the interior mirror.

There have been other problems associated with the use of convex mirrors that include double vision, eyestrain, and nausea. Based on research, the agency determined that these problems could be minimized by placing certain restrictions on the mirror's design and by trading off correct speed and depth perception to achieve a greater field of view. If a vehicle has an interior mirror that does not meet the field of view requirements and the manufacturer opts to use a convex mirror on the passenger side, the convex mirror must meet the following three requirements: (1) When the radius of curvature is measured at ten different positions as specified in the standard, none of the radii of curvature readings may deviate from the average radius of curvature by more than plus or minus 12.5 percent; (2) the mirror must be indelibly marked at the lower edge of the mirror's reflective surface with the words "Objects In Mirror Are Closer Than They Appear"; and (3) the average radius of curvature cannot be less than 889 millimeters (mm) and not more than 1,651 mm.

The first requirement, that the convex mirror's radius of curvature may not deviate more than plus or minus 12.5 percent from the average radius of curvature, is to ensure that the mirrors have a reasonably constant radius of curvature. This minimizes changes in image distortion across the face of the mirror. This helps reduce many of the

reported instances of double vision, nausea, and dizziness.

The second requirement specifies that a visible warning be marked on the mirror's reflective surface. Because the mirrors cause distance and speed distortion, *i.e.*, the objects appear further away in the mirror, the agency felt that a warning should be placed in plain view to the vehicle operator. This is the rationale for the second requirement, that the mirrors be labeled with "Objects in Mirror Are Closer Than They Appear." If the driver is aware of this label, the driver will be aware that this mirror is not a flat mirror, and hopefully not make a mistake in judgment.

The third requirement, which specifies a minimum and maximum radii of curvature of the mirrors, is to ensure that the mirrors on different vehicles possess some level of uniformity. For example, if a person became accustomed to driving a vehicle with a passenger-side mirror radius of curvature of 2,500 mm, the same person might experience disorientation if he or she drove a vehicle with a passenger-side mirror radius of curvature of 500 mm. In Standard No. 111, the allowable range of radii of curvature of between 889 mm and 1,651 mm is based on a study performed by Vector Enterprises, Inc. (Vector) ["Passenger Vehicle, Light Truck, and Van Convex Mirror Optimization and Evaluation Studies," August 1980, DOT HS 805-695] in which a number of convex mirrors were evaluated. In this study, Vector found that a radius range of 1,016 mm to 1,524 mm provided the best results. The agency proposed this range in a 1978 notice of proposed rulemaking (NPRM) [43 FR 51657]. However, based on comments by manufacturers to the NPRM, the agency increased the range by 127 mm on each end.

Recent Innovations in Rearview Technology

Non-Planar Mirrors

Since the last significant changes were made to Standard No. 111 in 1982, there have been a number of innovations to rearview technology. The main innovation in mirror technology is the development of a hybrid mirror called an aspheric convex mirror (hereafter referred to as an "aspheric mirror"). Aspheric mirrors differ from the currently allowed convex mirrors in that they do not have a constant radius of curvature. Generally, these mirrors have a convex area with a large radius of curvature that provides a relatively undistorted view. Typically, this area constitutes approximately 60 to 80

percent of the mirror surface. In this portion of the mirror, the radius can be so large that it will appear to be flat (the radius of curvature of a flat mirror is infinity). The relatively flat portion of the mirror allows the driver to make more accurate speed and distance judgments about the adjacent vehicles than would be possible with a convex mirror. On mirrors currently being manufactured for the aftermarket and for use in other countries, the radius of curvature of this flatter area can range from 2,032 mm to 12,700 mm.

Extending from the large radius of curvature portion of the mirror outward, away from the vehicle, is another area in which the radius of curvature gradually decreases. This portion increases the field of view by smoothly transitioning from the large radius of curvature in the relatively flat portion to a much smaller radius. Because of the variation in radii of curvature, the outside portion of the mirror is distorted much like that of a convex mirror. This is how the larger field of view is attained. With this larger field of view, there could be a reduction or even an elimination of the blind spots that currently exist when flat mirrors are used. The most convex (outer) area of the aspheric mirror can provide a field of view that is as much as 30 percent larger than that of a similarly sized convex mirror with a uniform radius of curvature that satisfies the current standard.

Because these mirrors essentially provide two different types of views to the rear of the vehicle, some aspheric mirrors have an etched line delineating where the portion of the mirror that is the effectively flatter section ends and the more curved section begins. This is done to reduce confusion about which images are distorted and which are less so.

Video Systems

Due to the decrease in the cost of video monitoring equipment in recent years, manufacturers have begun to explore ways to incorporate this technology into motor vehicle rear vision systems. In these prototype systems, video cameras can be placed in almost any position on the interior or exterior of the vehicle. The cameras are wired to monitors in the forward of the vehicle so that they can be viewed by the driver. Because of the many possible mounting locations of the cameras, these systems can provide views to the driver that mirrors are not able to achieve.

There are companies that have already begun to implement this technology. In addition to the mirror