

Influence of Complying with FMVSS 226 (Ejection Mitigation) on Side Airbag Occupant Out of Position Injury Assessment

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ABSTRACT

The National Highway Traffic Safety Administration (NHTSA) has identified ejection mitigation as a top priority, issuing a final rule for FMVSS 226, Ejection Mitigation, in January of 2011 to set performance standards for a vehicle's ejection mitigation countermeasures to mitigate the risk of ejection through a vehicle's side window openings. The most likely countermeasures to be used for compliance with this standard are rollover activated curtain airbags that deploy from a vehicle's roof rail. However, this rule will most likely result in increases in the coverage area and inflator outputs of the curtain airbag; which may influence out-of-position occupant injury as measured in the test methods that have been outlined by the Side Airbag Out-of-Position Injury Technical Working Group (TWG). This paper presents a case study in which the out-of-position performance of a curtain airbag optimized for both ejection mitigation and side impact protection, as outlined per FMVSS 226 and FMVSS 214 respectively, is compared with that of one developed for side impact protection only for the same vehicle. Furthermore, the authors present a design concept that can be used to balance the requirements of FMVSS 226 with the injury risk from the deploying curtain airbag for out-of-position occupants.

CITATION: Dix, J., Hammoud, S., Cardinali, A., Mitchell, A. et al., "Influence of Complying with FMVSS 226 (Ejection Mitigation) on Side Airbag Occupant Out of Position Injury Assessment," *SAE Int. J. Passeng. Cars - Mech. Syst.* 5(1):2012, doi:10.4271/2012-01-0466.

INTRODUCTION

Ejections have a significant impact on occupant injuries in motor vehicle crashes, representing 27 percent of motor vehicle occupants fatally injured in 2009 with 6,692 fatalities [1]. In November of 2006, NHTSA published details of a component test method being used for researching ejection mitigation counter measures, which was being considered for rule making [2]. The agency's test consisted of a linearly guided impactor that projected an 18 kg impacting mass in the shape of a featureless head-form. This 18 kg mass was designed to represent the impacting mass of a 50th percentile male occupant (AM50). The test method outlined up to four impact locations on each of the daylight openings to which the evaluated countermeasure was applied. Using a potentiometer, the excursion of the head-form beyond the inside glazing surface of the daylight opening was measured. At the time, NHTSA was researching two proposals summarized in [Table 1](#). Both proposals consisted of two test conditions: the first test was conducted at a 1.5 second delay

(time after curtain deployment time); the second test was conducted at a 6 second delay. For the first test, there were two energy levels NHTSA was considering, 280 Joules and 400 Joules. The proposed impact energy for the second test (6 second delay) was 178 Joules. These test conditions were determined on the basis of dummy pendulum testing, video analysis of full scale rollover tests, and sled testing, replicating rollover and side impact events, outlined by NHTSA in the Advanced Glazing First Status Report [3]. [Figure 1](#) shows a typical setup for the NHTSA ejection mitigation research component test, and it outlines the method for determining the impact locations for each daylight opening.



Figure 1. NHTSA Ejection Mitigation Research Component Test Setup.

Table 1. NHTSA Ejection Mitigation Research Component Test.

	Impactor Mass	Test Energy	
		1.5 second delay	6.0 second delay
Proposal 1	18 kg	400 Joules Test Speed = 24 km/h	178 Joules Test Speed = 16 km/h
Proposal 2		280 Joules Test Speed = 20 km/h	

In December of 2009, NHTSA issued a notice of proposed rule making (NPRM) for Federal Motor Vehicle Safety Standard (FMVSS) No. 226 “Ejection Mitigation” [4]. In the NPRM, the agency proposed a component test based on ‘Proposal 1’ of its research test method with the first test conducted at an impact energy of 400 Joules (24 km/h) at 1.5 seconds after the ejection mitigation counter measure has been deployed. A second test is conducted at an impact energy of 178 Joules (16 km/h) with a 6 second delay.

NHTSA expected most OEM's would use rollover activated curtain airbags to comply with FMVSS 226. However, curtain airbags developed for ejection mitigation must also provide occupant protection in side impacts per FMVSS 214 “Side Impact Protection” [5]. Additionally, mitigating the risk of injury from deploying curtain airbags to out-of-position occupants must also be considered. As such, care should be taken to balance these performance requirements when developing the restraint systems. In previous work, the authors focused on occupant energy levels during rollovers [6]. Results of a simulated dolly test were presented in which the observed maximum energy of an unbelted AM50 occupant was 207 Joules, which was significantly less than the 400 Joules the agency's was proposing in the NPRM. It was also demonstrated that optimizing the air bag pressure for the ejection mitigation test at the 400 Joules level resulted in increased HIC values in the FMVSS 214 oblique pole side impact tests (37% and 42% increases for the AM50 and AF05 occupants, respectively). The findings of this study are summarized in Figures 2 and 3 respectively. The authors recommended reducing the ejection mitigation test to 20 km/h, with impact energy of 280 Joules, the lower test speed previously considered by NHTSA, rather than the 24 km/h speed noted in the NPRM. Based on feedback during the NPRM commenting period, as well as a more detailed analysis of the data available to it, the agency issued a final rule for FMVSS 226 in January 2009 in which

it revised the impact speed for the higher speed test from 24 km/h to 20 km/h, thus reducing the energy to 280 Joules [7].

With the rapid adoption of airbags for side impact protection, including curtain airbags, in the early 2000's the industry in cooperation with the Insurance Institute for Highway Safety (IIHS) established a Technical Working Group (TWG) to establish a recommend procedure to evaluate the injury risk to occupants posed by the deploying airbags. In 2003, the TWG published the “Recommended Procedure for Evaluating Occupant Injury Risk from Deploying Side Airbags” [8]; which includes test methods and performance criteria. Curtain airbags developed to meet the requirements of FMVSS 226 and FMVSS 214 will tend to have increased side window coverage compared with curtain airbags developed to FMVSS 214 only. These larger curtain airbags will tend to have higher inflator outputs with increased rise rates in order to meet the in position requirement for side impact protection with the increase coverage required for FMVSS 226. These changes to the curtain airbag to meet the requirements for ejection mitigation may influence the injury risk for out-of-position occupants; thus, the intent of the current study is to assess the impact on out of position injury as measured in the TWG when developing a curtain airbag to meet the requirements of FMVSS 226.

METHOD

A mid-sized SUV with a ‘baseline’ curtain airbag that was optimized to provide head protection as outlined in FMVSS 214 was selected as the surrogate for this study. An ejection mitigation curtain airbag was developed for the surrogate vehicle to meet the requirements of FMVSS 226 while maintaining the performance for side impact as measured by HIC in the FMVSS 214 Oblique pole test of the baseline airbag. Figure 4 overlays the FMVSS 214 occupant head locations with that of the FMVSS 226 impact points. As can be seen the daylight opening for the side window can be divided into two zones. A side impact zone which covers the occupant head locations for the 50th (AM50) percentile adult male and 5th percentile adult female (AF05) occupants as dictated by FMVSS 214, and a larger ejection mitigation zone that extends forward and below the side impact zone to cover the impact points outlined by FMVSS 226. The baseline curtain airbag that had been optimized considering side

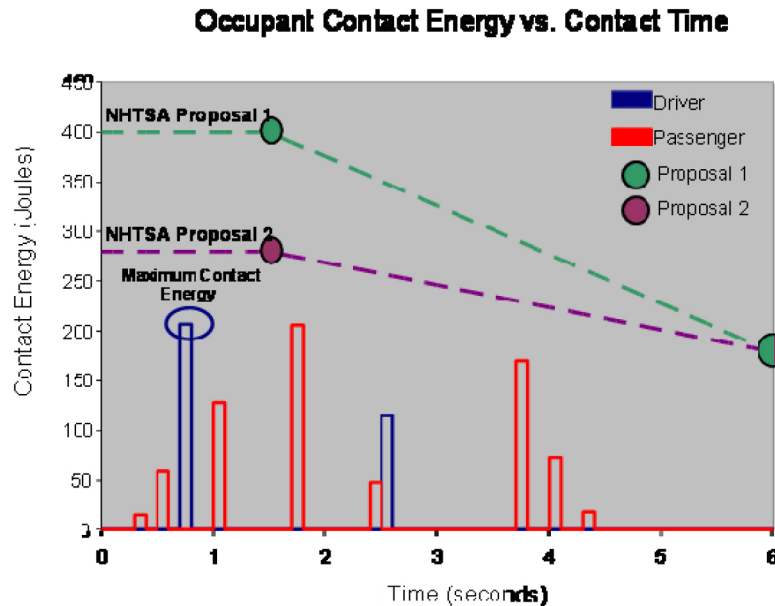


Figure 2. Occupant contact energy measured during FMVSS 208 dolly rollover test simulation compared with the two NHTSA component test proposals[6].

impact only provided coverage for the side impact zone only. In developing the ejection mitigation curtain airbag to meet FMVSS 226, the peak pressure and bag loft of the baseline airbag were maintained in order to ensure equivalent performance for side impact head protection (considering HIC and energy absorption). The coverage was extended forward to cover the forward most (No. 1) impact point.

A sensitivity study was then conducted to determine vertical height required to meet the excursion requirements of FMVSS 226 for the lower impact points (No. 1 and 3). For this, linear impact testing was conducted per FMVSS 226 at 20 km/h. This speed was selected based on the higher energy level representing a more severe condition for the curtain airbag. All testing was conducted with the curtain airbag pressurized with shop air to the pressure expected at 1.5 seconds after deployment. Four vertical heights relative to the vehicle waistline were considered, -100 mm, 0 mm, +100 mm, +150 mm (Figure 5 outlines the vertical height used for this study). The -100mm overlap was selected as the starting point for the study because it matched the vertical height of the base line airbag. Impact point No. 1 consistently showed the highest excursion, thus that point was used for the sensitivity study. Figure 6 shows the excursion at point No. 1 as the curtain airbag vertical height was increased. The -100 mm overlap with the waistline did not contain the head form. The 0 mm overlap contained the head form, but did not meet the 100mm excursion beyond the plane of the window glazing called out in FMVSS 226. The 100 mm overlap with the vehicle waistline met the excursion criteria with an excursion of 90 mm; furthermore, there wasn't any significant reduction in the measured excursion when the overlap was further increased to 150mm. This was because in the test with

the 100mm overlap, the overlap with the door trim was maintained during the duration of the test, as such there was no measurable benefit to extend the bottom of the curtain airbag beyond the 100 mm overlap with the waistline. Therefore, the 100 mm overlap was selected as the vertical height for the ejection mitigation curtain airbag; which is shown in Figure 7 with an outline comparing the coverage of the ejection mitigation airbag with that of the baseline airbag developed for side impact only.

Once the coverage was decided, the inflator output and rise rate were sized based on the curtain airbag volume. Testing was then conducted with the live inflators for both the ejection mitigation and FMVSS 214 oblique pole tests to confirm the performance. The ejection mitigation testing was conducted at 20 and 16 km/h at the 1.5 and six second delays respectively as outlined in FMVSS 226. To evaluate the side impact performance, a linear impact testing method was used to simulate the FMVSS 214 oblique pole test. A 254 mm simulated rigid pole was positioned directly behind the Head C.G. impact location for both the AM50 and AF05 occupants. The test setup is shown in Figure 9. A Hybrid III AM50 half head-form was mounted on a linear actuator with an effective mass of 5.5 kg. Testing was conducted for both the AM50 and AF05 seating positions shown in Figure 4. The impact speed was adjusted to achieve the desired impact energy for the AM50 or AF05 occupants depending on what position was being tested. The head injury criterion (HIC) was predicted based on the peak force measured in the component test.

There are three test conditions outlined in the TWG recommended practice pertaining to evaluating the injury risk for deploying roof mounted curtain airbags. These three tests,

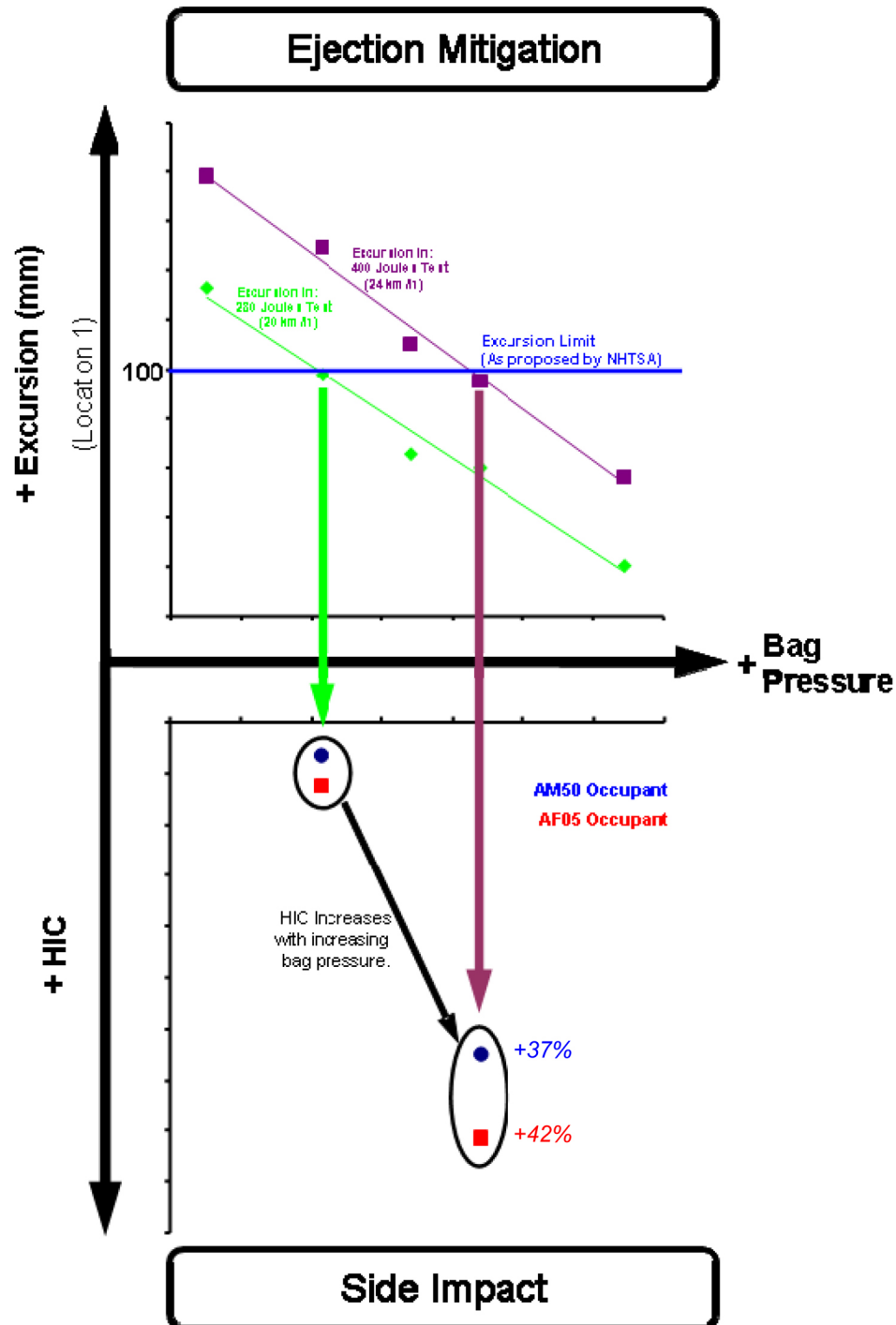


Figure 3. Curtain airbag pressure sensitivity considering ejection mitigation and side impact. [6]

listed below, were used to compare the out-of-position performance of the ejection mitigation curtain airbag with that of the baseline side impact curtain airbag.

- 3.3.5.1 6 - Year old (AC06) Inboard facing on booster seat
- 3.3.5.2 5th percentile Female (AF05) Forward facing with raised seat
- 3.3.5.3 5th percentile Female (AF05) Inboard facing with raised seat

For this study the seat mounted airbag was not deployed in order to provide a comparison of the performance of the curtain airbag alone, without the influence of the seat mounted airbag (Figures 10 shows the test setup for each of the three test conditions). In each of the three test conditions the dummy's head was positioned in the cross car (lateral) position such that it was in the deployment path of the airbag per the TWG recommended practice.