

A Study of Occupant Ejection Mitigation in Side Impact Crashes

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ABSTRACT

The National Highway Traffic Safety Administration (NHTSA) has identified ejection mitigation as a top priority, issuing a notice of proposed ruling making (NPRM) in December of 2009. The NPRM proposes a linear impact test that uses a featureless head-form to impact a vehicle's side windows' daylight opening at various positions. The test measures the excursion of the head-form beyond the plane of the window glazing. The intention is to evaluate the ability of a vehicle's ejection mitigation system, such as the curtain airbag or other vehicle features, to manage the impactor energy and limit excursion. The NPRM proposes a test conducted 1.5 seconds after the ejection mitigation countermeasure is deployed at an impact speed of 24 km/h with a mass of 18 kg (400 Joules). This test condition is intended to consider both rollover and side impact crashes. While the majority of the research published to date has concentrated on occupant ejections in rollover crashes, there is little published literature focusing on side impact crashes. The authors will present the results of a study in which computer modeling using a generic vehicle environment was used to estimate an ejection representative energy level for side impact crashes that can be employed for evaluating ejection mitigation systems. The effects of factors such as vehicle architecture and interior layout were considered in this study.

INTRODUCTION

Ejections have a significant impact on occupant injuries in motor vehicle crashes, representing 8,605 fatalities as well as 20,000 injuries in 2007 [1]. For 2008, it has been reported

that 20% of fatally injured passenger car occupants were ejected, either totally or partially [2]. As such, NHTSA has been studying rollovers for a number of years. In November of 2006, NHTSA published details of a component test method being used for researching ejection mitigation, which was being considered for rule making [3]. The agency's test consists of a linearly guided impactor that projects an 18 kg impacting mass in the shape of a featureless head-form. This 18 kg mass is designed to be representative of the impacting mass of an AM50 occupant. Four impact locations are tested on each of the daylight openings to which the evaluated countermeasure is applied. Using a potentiometer, the impactor measures the excursion of the head-form beyond the inside glazing surface of the daylight opening. 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 considered, 280 Joules or 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 [4]. [Figure 1](#) shows a typical setup for the ejection mitigation component test, and it outlines the method for determining the impact locations for each daylight opening.

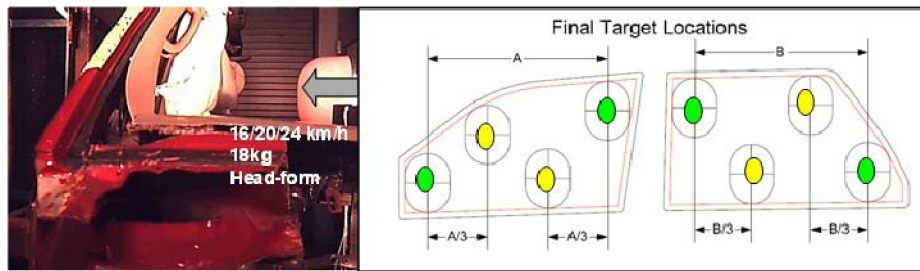


Figure 1. NHTSA Ejection Mitigation Research Component Test Setup.

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” [5]. In the NRPM the agency proposes 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) 1.5 seconds after the curtain airbag has been deployed. A second test is conducted at an impact energy of 178 Joules (16 km/h) with a 6 second delay.

The benefits of ejection mitigation, especially with respect to complete ejection, are primarily assumed to be for unbelted occupants. A primary challenge in creating design, testing, and regulatory requirements for an ejection mitigation countermeasure is in understanding the energy levels that must be absorbed and contained. The goal is for the countermeasure to contain the energy levels of unbelted occupants while not inflicting additional injuries to restrained occupants. Ejection mitigation requirements may result in increased side curtain air bag stiffness. Hence, it is important to balance the requirements of ejection mitigation with the injury prevention targeted by other side impact regulation such as FMVSS 214: Side Impact Protection.

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 less than either of the agency's proposals. It was also demonstrated that optimizing air bag pressure for the higher energy levels (400 Joules) resulted in increased HIC values in the FMVSS 214 oblique pole side impact tests, as compared to optimizing pressure for the lower energy levels NHTSA was studying (280 Joules). The findings of this study are summarized in Figures 2 and 3 respectively. The authors recommended optimizing the ejection mitigation test to 20

km/h (280 Joules) rather than the 24 km/h speed noted in the NPRM.

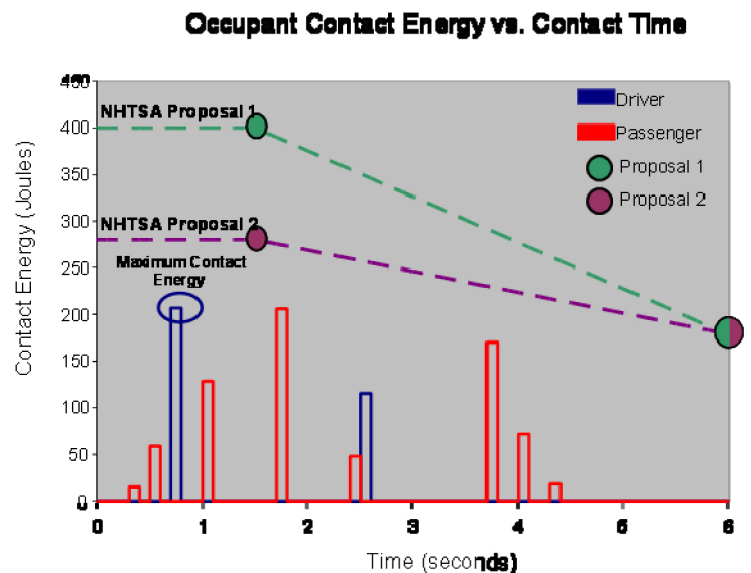


Figure 2. Occupant contact energy measured during FMVSS 208 dolly rollover test simulation compared with the two NHTSA component test proposals.

Ejection is not a phenomena associated only with rollover crashes. Injuries and fatalities resulting from occupant ejection can occur in planar collisions as well. During NHTSA's advanced glazing research, Willke et al. estimated that of 7,636 fatalities in 1999 involving partial or complete ejections through glazing, 2,864 of those occurred in planar crashes [2]. The NPRM for FMVSS 226 used 1997-2005 NASS CDS data adjusted to 2005 FARS level to estimate that 6,174 fatalities occurred in crashes involving ejections through side windows, including the first two seating rows [5]. Of these 6,174 fatalities, 1,568 occurred specifically in side impact planar collisions. In a more recent analysis, the NHTSA National Center for Statistics and Analysis (NCSA) examined vehicle occupants in fatal crashes from 2003 to 2007 (FARS data) to study ejection factors. In these crashes, 54,505 occupants were ejected, including both fatalities and survivors. Approximately 72% (39,312) of these 54,505 occupants were involved in rollovers. Approximately 21%

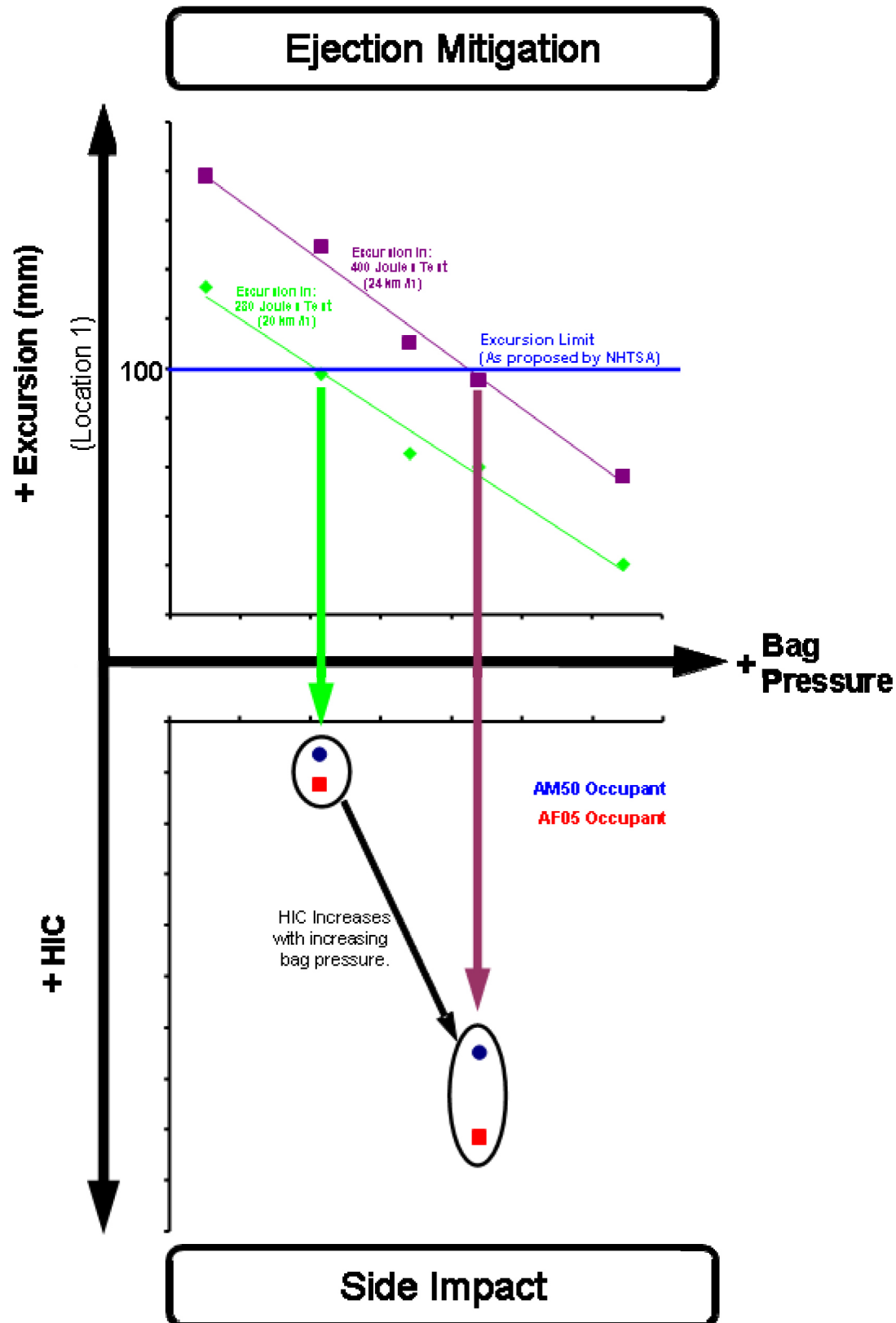


Figure 3. Curtain airbag pressure sensitivity considering ejection mitigation and side impact.