

Examination of a Properly Restrained Motorsport Occupant

2013-01-0804

Published
04/08/2013John Patalak and Thomas Gideon
NASCARJohn Melvin
Tandelta

Copyright © 2013 SAE International

doi:10.4271/2013-01-0804

ABSTRACT

Throughout the first decade of the twenty first century, large improvements in occupant safety have been made in NASCAR®'s (National Association for Stock Car Auto Racing, Inc.) race series. Enhancements to the occupant restraint system include the implementation and advancement of head and neck restraints (HNR), minimum performance requirements for belts and seats and the introduction of energy-absorbing foam are a few highlights, among others. This paper summarizes three non-injury case studies of actual on-track incidents, including the acceleration pulses, principal direction of force, restraint systems used and driver anthropometry information. Also discussed are the NASCAR personal safety equipment requirements as well as frontal, oblique and side sled testing data of similar input acceleration magnitudes for the Hybrid III (H-III) fiftieth percentile male anthropomorphic test device (ATD).

INTRODUCTION

Over the last ten years, many papers have been published on a wide range of motorsports safety topics. Some of these papers have focused on specific safety advancements, such as the SAFER® (Steel And Foam Energy Reduction) barrier, head impact padding, occupant computer modeling, incident data recorders and restraint performance requirements [1,2,3]. The purpose of this paper is to show several real world examples of the performance of these individual safety contributions as a total occupant safety system.

Each race season NASCAR Field Investigators gather vehicle impact acceleration data, document vehicle restraint information, and take photographs and notes for

approximately 600 on-track incidents. Periodically this information along with driver medical information is reviewed from a database by NASCAR Safety Engineers. Several previous publications have parsed, summarized and modeled this incident database information, for mean principle direction of force (PDOF), peak accelerations, change in velocities (ΔV), injury risk and many other factors [4,5].

For this paper three on-track incidents were chosen for detailed presentation. The incident selection criteria included:

- primarily frontal, side or frontal oblique ($\sim 30^\circ$) impact directions
- a single acceleration pulse (not multiple impact events)
- complete driver restraint information
- vehicle and/or foreign object intrusion into the occupant space did not occur
- driver did not sustain injuries significant enough to prevent participation in the next race

While cataloged incidents include PDOFs of all direction with largely varying peak acceleration, magnitudes and velocity changes that exist, effort was also made to choose incidents for inclusion whose acceleration magnitude and PDOF corresponded to laboratory sled testing. The standard angles used during seat, seat belt and head and neck restraint sled testing include 0° frontal, 30° right frontal oblique and 90° side orientations.

The selected case studies and sled test data for this paper are highlighted against a PDOF polar plot and acceleration versus

ΔV plot, shown in [Figures one](#) and [two](#) from the 2002 through 2008 NASCAR incident data base.

The average weight of active NASCAR drivers in 2012 was 178 pounds, with an average stature of 69 inches. The average age of active NASCAR drivers in 2012 was 33 years with a rule limited minimum of 18 years. [Figure three](#) shows the anthropometric data of active 2012 NASCAR drivers. The fiftieth percentile American male (AM) H-III ATD is also shown for comparison [6].

At each race event NASCAR officials conduct safety inspections and survey the personal safety equipment used in each vehicle. The survey is recorded directly into a database via a touchscreen tablet and is related to vehicle number, driver name, incident data recorder serial number, vehicle chassis identification number and other parameters. When an incident occurs on the race track a separate software package is used to create an incident report. The restraint survey data is automatically paired with the incident report, effectively linking restraint, driver, vehicle, acceleration data, photos, video and other information into one incident file. The following bullet points show the restraint survey information which is gathered for every vehicle at every NASCAR National Series event.

- Vehicle #
- Head Net(s) Used
- Seat Brand
- Rib/Chest Support(s) Used
- Belt Brand
- Belt Style
- Belt Adjuster Style
- Belt Adjuster Location
- Belt Adjuster Type
- Belt Shoulder Mount Type
- Leg Divider Used
- HNR Brand
- HNR Tether Type
- Helmet Removal Device Used
- Helmet Brand
- Composite Seat S/N
- Incident Data Recorder S/N

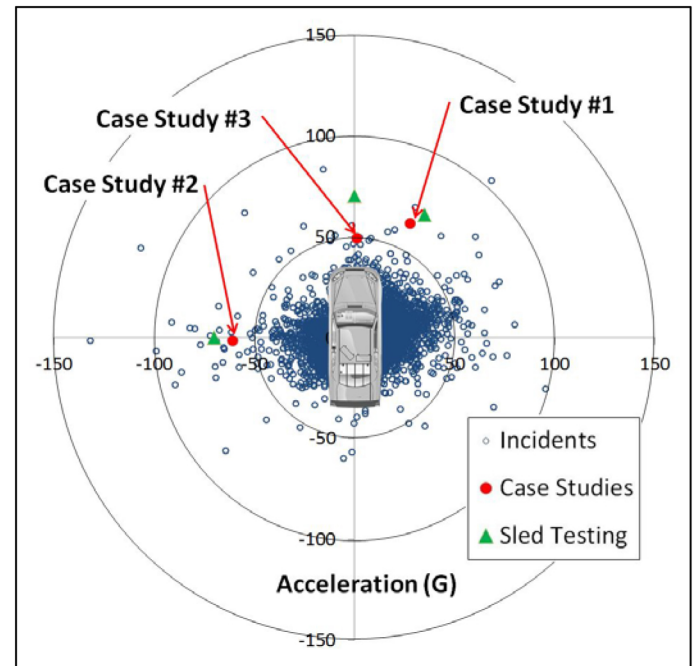


Figure 1.

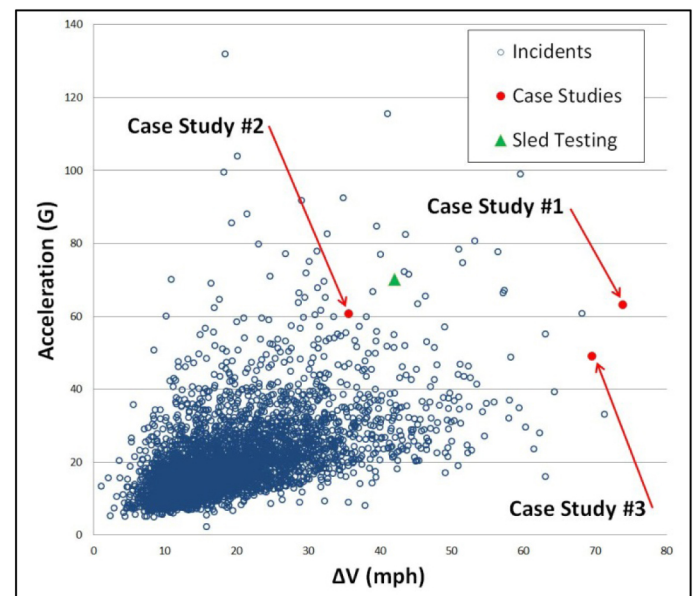


Figure 2.

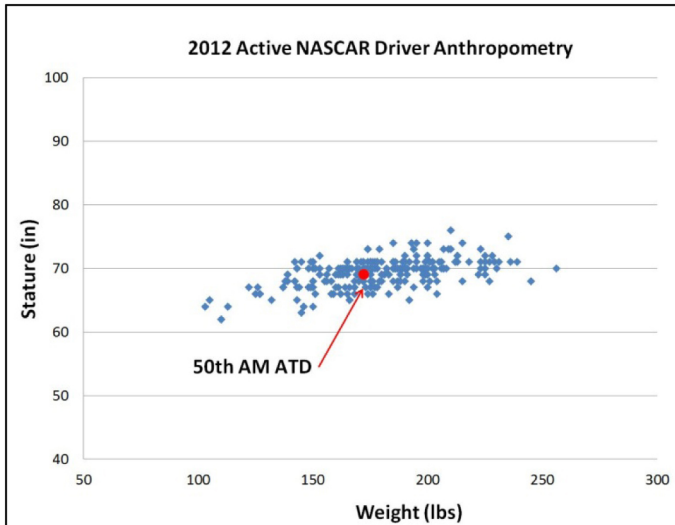


Figure 3.

DISCUSSION

Personal Safety Equipment

Section 20-17, Personal Safety Equipment, of the NASCAR rulebook identifies the required safety equipment competitors must use during NASCAR sanctioned competition. [Table one](#) shows the required personal safety equipment for drivers, the associated performance specifications for each and a corresponding notation for [Diagram one](#).

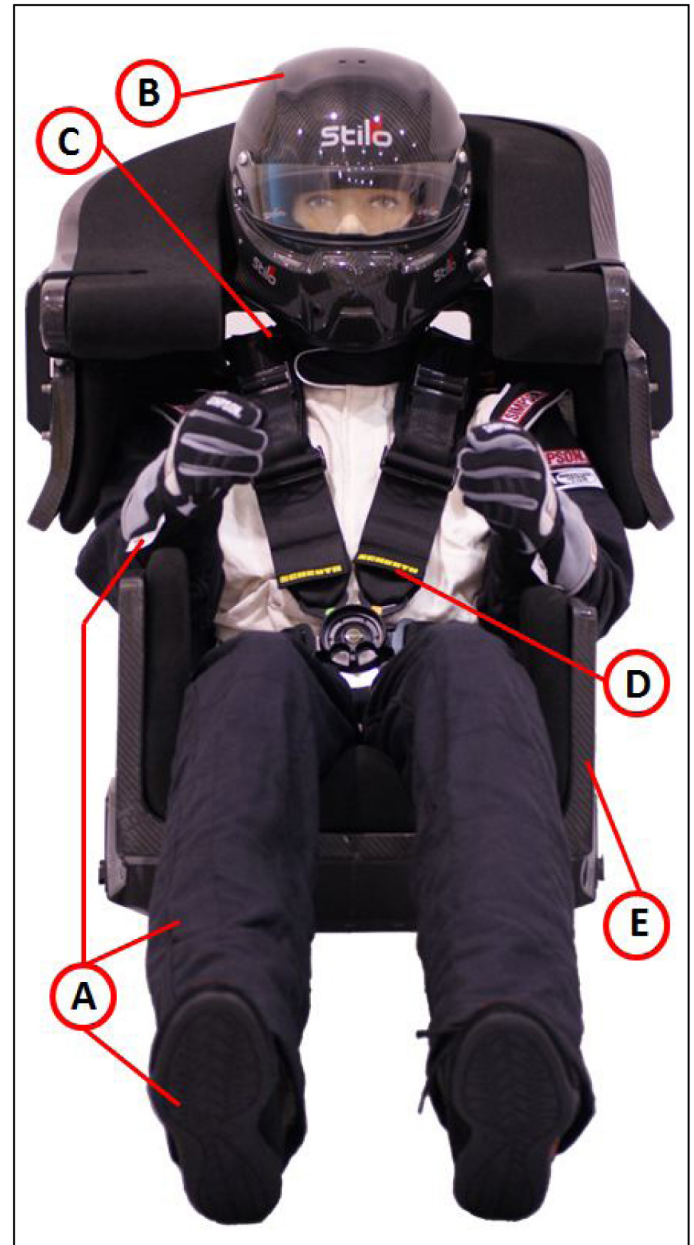


Diagram 1.

The SFI Foundation (SFI) specifications are industry accepted specifications which establish uniform test procedures and minimum standards for evaluating and determining performance capabilities of safety equipment. The specifications are used as minimum guidelines for construction and evaluation of products. The personal safety equipment compliant with the specifications shown in [Table one](#) was used in each of the presented case studies. [Diagram one](#) shows all of this equipment.

Table 1.

Personal Safety Equipment		
Equipment	Specification(s)	Diagram 1 Letter
Fire resistant uniform, gloves, shoes & accessories	SFI 3.2A/5, 3.3	A
Helmet	FIA 8860-2004, 8860-2010 Snell SA2005, SA2010, SAH2010 SFI 31.1/2005	B
Head & Neck Restraint (HNR)	SFI 38.1 + NASCAR rulebook	C
Seat Belts	SFI 16.5 + NASCAR rulebook	D
Seats	SFI 39.1 + NASCAR rulebook	E

Helmets

As [Table one](#) shows, helmets meeting several different performance specifications are acceptable for use in NASCAR competition. For the impact portion of the Snell standard SA2010 specification, a fire resistant full face helmet with face shield is used with a 10.3 lb (4.7 kg) head form inside the helmet. The average size helmeted head form drops at a velocity of 17.3 mph (7.75 m/s) onto a flat, hemispherical, roll bar, and edge surface anvil. The head form measured acceleration must not exceed 275 G's. SA2010 has different requirements for larger and smaller head sizes. The FIA 8860-2010 standard requires a 11.0 lb (5.0 kg) head form, 24.6 mph (9.5 m/s) drop speed with a 300 G maximum acceleration. FIA 8860-2010 also requires a 33% increase in helmet shell penetration resistance. The Snell SAH2010 certification carries the same helmet performance requirements as Snell SA2010, but also includes evaluation of the helmet hardware for the attachment of HNR tethers. A HNR to helmet tether anchorage system is shown in [Diagram two](#).

Head & Neck Restraints

Many papers have been previously published on the HANS Head and Neck Support device [7,8,9]. The original SFI 38.1 Head and Neck Restraint Systems specification was released in 2004 for use in motorsports. It requires two frontal and one 30° right frontal sled test for each submitted HNR device using a H-III fiftieth percentile male ATD. For each test the maximum upper neck tension may not exceed 2,500 N from zero through eighty milliseconds and may not exceed 3,200 N from eighty to one hundred and twenty milliseconds. This

performance criterion with respect to time is done to account for ATD response artifacts during the rebound phase of the event. A flame resistance test is also applied to the tether and device surface. For a HNR device to be accepted for use in NASCAR, the device must be in compliance with SFI 38.1 and must also be reviewed and recommended for acceptance by the NASCAR Head and Neck Study Group. The two HNR devices currently acceptable for use in NASCAR are shown in [Diagram three](#).



Diagram 2.



Diagram 3.

The SFI 38.1 sled test input pulse and resulting ΔV are shown below in [Figure four](#).

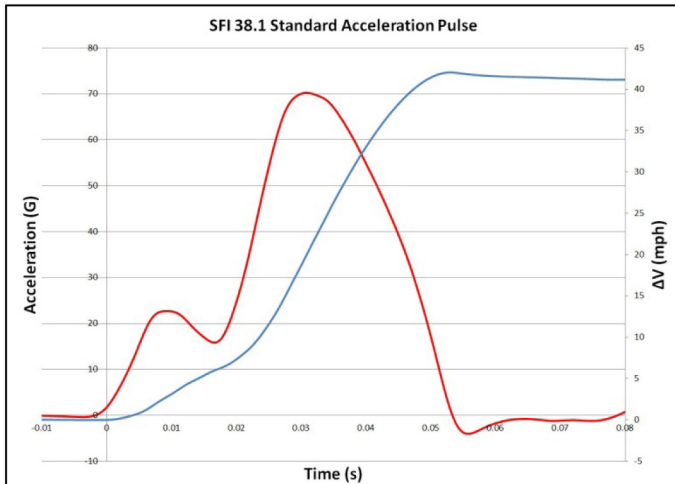


Figure 4.

Belt Restraint Systems



Diagram 4.

Only belt restraint systems meeting the SFI 16.5 Stock Car Driver Restraint Assemblies specification may be used in NASCAR. The SFI 16.5 specification is a quasi-static test that loads the entire restraint system assembly through a body block to 11,500 lbf (51.1 kN). The restraint system must withstand the load with no failures or separation of any webbing in the assembly. Both two inch and three inch wide webbing are permissible. A 6-point restraint system became mandatory in 2007 and a 7-point

system is now recommended for use in NASCAR. The 6-point restraint has two anti-submarine, or crotch straps, while the 7-point system has the same two anti-submarine belts, plus a 3rd negative-G strap. [Diagrams four](#) and [five](#) show examples of these restraints. Note the three inch wide lap belts in [Diagram four](#) and the two inch wide lap belts in [Diagram five](#).



Diagram 5.

Positioning of the crotch belts is critical for optimum performance and must be compatible with the seat and/or chassis. The SFI Seatbelt Installation Guide For Upright Seating recommends a -10° to -20° (rearward) angle on the crotch straps, depending on the seat design [10]. When using a 7-point system, the 7th point is recommended to follow the chest line of the driver and provides additional vertical occupant restraint and lap belt stability and also allows anchoring the crotch belts at the lap belt anchors as shown in [Diagram seven](#). [Diagrams six](#) and [seven](#) show the six and seven point systems, respectively.

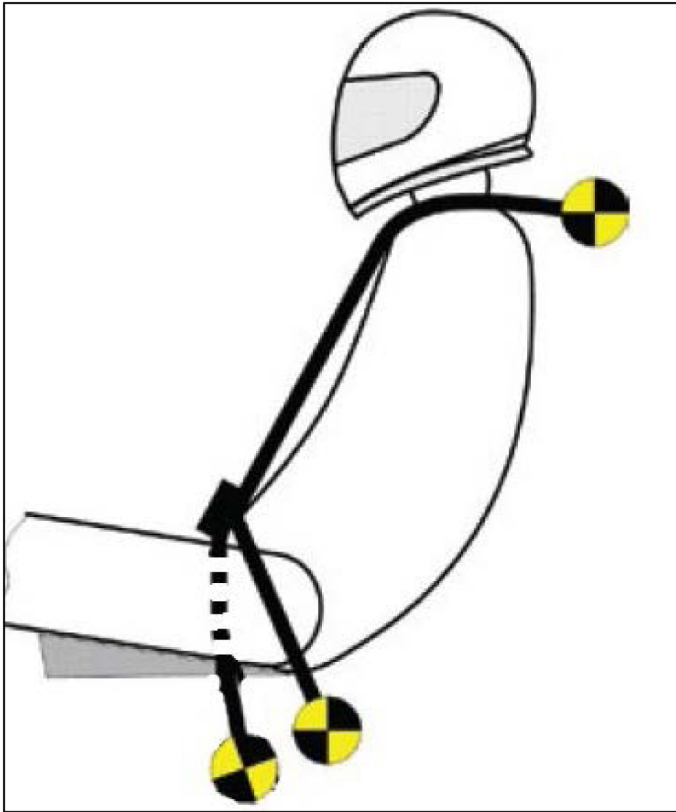


Diagram 6.

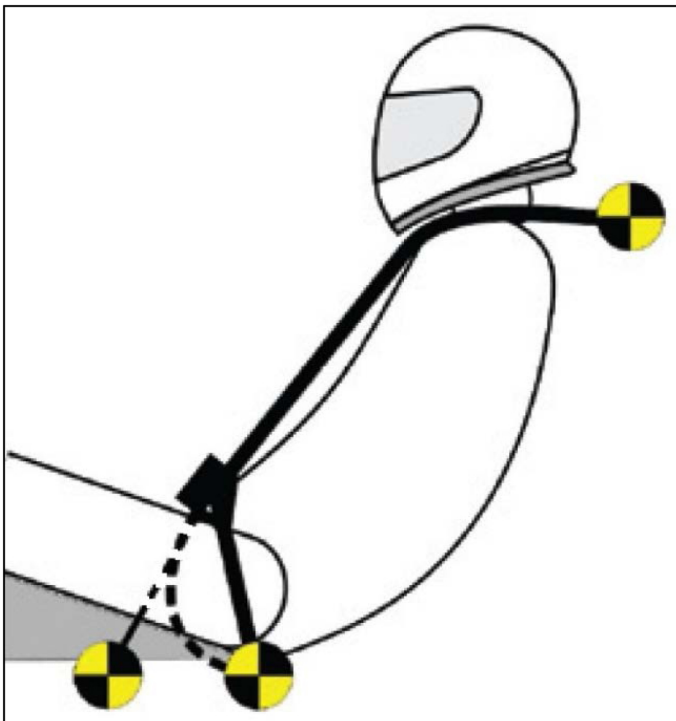


Diagram 7.

Additional shoulder belts are also commonly used in NASCAR racing. These additional belts are commonly referred to as “double shoulder belts” or “over/under shoulder

belts”. They consist of a three inch wide belt which rests on the body. A second upper two inch wide belt rests on top of the HNR device. Each belt has its own adjuster and seat or chassis mounting location. The upper and lower belts merge into a single belt before connecting to the cam-lock or latch link. The body belt mounting may be positioned to achieve a downward belt angle between -10° to -30° [10]. This downward component of the body belt provides additional vertical restraint. The upper belt is mounted at 0° to -10° downward [10]. In a frontal impact, due to its orientation, the upper belt carries the majority of the load, preventing vertical occupant overloading by the downward angled body belt. However, during vertical acceleration (roll-over) events the downward angled body belt works more efficiently as it has a larger vertical component. When used with a 6-point restraint system, the over/under shoulder belts system is referred to as an 8-point restraint. A 9-point system includes the third crotch strap added to the over/under shoulder belt system. Examples of the eight and nine point restraint systems are shown in [Diagrams eight and nine](#). [Diagram ten](#) shows the 9-point restraint geometry.



Diagram 8.