INITIAL EVALUATION OF ADVANCED AIR BAGS IN REAL WORLD CRASHES

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ABSTRACT

The performance of occupant protection systems, especially air bags, is of high interest to the National Highway Traffic Safety Administration (NHTSA). Since 1972, the NHTSA has operated a Special Crash Investigations (SCI) program, which provides the agency with the flexibility to acquire detailed engineering information quickly on high-visibility traffic crashes of special interest. The SCI program collects in-depth crash data on new and rapidly changing technologies in real world crashes. NHTSA uses the data collected in this program and others to evaluate rulemaking actions. The data are also used by the automotive industry and other organizations to evaluate the performance of motor vehicle occupant protection systems such as air bags.

In May of 2000, the NHTSA issued a Final Rule upgrading Federal Motor Vehicle Safety Standard Number 208. In this advanced air bag rule, significant changes were specified in the frontal occupant protection requirements for light passenger vehicles. These changes were to be phased in over several years. These changes included adding requirements for protecting small adult female occupants, adding requirements to minimize the risk of deploying air bags to out-of-position (OOP) children and small adult occupants, increasing the requirements for belted occupants, and reducing the test speed for the unbelted 50th percentile male occupants.

For the past two years, NHTSA's Special Crash Investigations office has been researching crashes involving of vehicles equipped with advanced air bag systems. The purpose of this effort was to keep the Agency and manufacturers informed of the real world performance of these advanced systems. This paper will discuss the protection afforded the occupants in vehicles equipped with these systems; also known as Certified Advanced 208 Compliant (CAC) systems. Since data collection is ongoing, this paper will be limited to those crashes that were researched in the SCI program.

Topics covered in this paper will include: case selection criteria; make and model applicability; age / sex of front seat occupants; airbag deployment stage; safety belt usage; event data recorder (EDR) download applicability; damage severity; injury outcomes in the selected cases; and sample case data. Completed SCI case studies are available via the World Wide Web at www.nhtsa.dot.gov. See the "**SCI DATA AVAILABILITY**" section at the end of this paper for further details.

BACKGROUND

NHTSA performs research and develops safety programs and standards in an effort to reduce the toll of deaths, injuries, and property damage from traffic crashes. In-depth field investigations on crashes with an air bag deployment are conducted in the SCI program under the auspices of the National Center for Statistics and Analysis (NCSA). SCI cases are an anecdotal data set used to examine and evaluate the latest safety systems. Unlike NHTSA's National Automotive Sampling System (NASS) the SCI program is not intended to be a statistically representative database. Therefore, national trends cannot, and should not be inferred from the data. These SCI investigations play a vital role by providing data relative to real world events. Added details on SCI investigations can be found in 17th ESV, Chidester and Roston (2001)[1].

Starting in the 2000 model year, some manufacturers started to incorporate advanced air bag "features" into certain products. These advanced features included things such as seat track sensors to disable air bags from deploying when the seat track was in the forward most position; dual stage air bag inflators to tailor air bag deployments to the crash severity; safety belt sensors to determine the relative risk to the occupant(s); safety belt pretensioners to remove excess slack in the early moments in the crash phase; and safety belt load limiters to spool out part of the safety belt during the crash phase for the occupants to "ride down" the crash forces.

As indicated in the May of 2000 Final Rule, manufacturers have until August 31, 2006 to phase-in compliance with advanced air bag requirements specified in Federal Motor Vehicle Safety Standard (FMVSS) 208. This new advanced air bag standard details the test parameters and conditions that must be met to be in compliance with this advanced requirement.

Starting in the 2003 model year Honda and General Motors introduced a total of 11 models that were certified advanced 208 compliant (CAC). In the 2004 model year that number grew to 13 manufacturers and 40 models. The SCI program utilized its network of resources to identify crashes where there was an above referenced CAC vehicle involved in the crash, and the vehicle damage was still available for inspection.

SCI performs roughly 200 case investigations a year for the NHTSA. These case investigations encompass all types of cases relative to NHTSA priorities and therefore the CAC cases are only a part of the annual cases SCI investigates.

CASE SELECTION

A total of seventy-one (71) cases were evaluated for the information contained in this paper. As indicated, SCI has a network of resources across the country to provide notification of cases of particular interest. This network includes: three SCI field offices; 27 National Automotive Sampling System (NASS) field offices located in 17 States; 10 field offices for NHTSA's Crash Injury Research and Engineering Network (CIREN); various law enforcement agencies; insurance companies; and emergency medical service providers; along with the general public.

In an effort to gain more exposure to these types of vehicles, Nationwide Mutual Insurance Company agreed to work with SCI on this effort. Nationwide was able to supply electronic listings of vehicles meeting our CAC criteria, and in turn we were able to identify a greater population of crashes in which to assign SCI cases for research.

To make notification as simple as possible, SCI provided the various organizations a listing of the vehicles that were certified to the new rule. The organizations were then requested to inform us when a crash occurred that involved one of these vehicles. No other specific parameters were indicated. The purpose of this effort was to collect information on a wide variety of crashes ranging from minor to severe.

Once the crash was identified to NHTSA, SCI screened the crash report and ascertained CAC vehicle involvement. SCI was specifically looking to target "near frontal" crashes in this data collection effort. Therefore rear plane impacts along with side impacts outside the 10 o'clock to 2 o'clock principle direction of force were generally excluded. As the breakdown will show, a wide spectrum of cases were identified and investigated ranging from minor frontal crashes to more severe multiple event crashes and various crash configurations. The purpose of this approach was to not limit the data collection efforts to only those cases where the air bag deployed. Crashes where the air bag system was not commanded to deploy provide valuable information as to any possible risks associated with not deploying the air bag in less severe crashes.

Additionally, strong emphasis was given to the availability of event data recorder (EDR) information. With these advanced systems, the only way the field crash investigators can determine the deployment level of the air bag (e.g., stage 1 or stage 2 deployment) was through retrieving the EDR data. The General Motors products had a commercially available tool to download the data from the air bag control module. These data were included in the case reports indicating certain precrash, and crash information. Other manufacturers do not have a commercially available tool to download stored air bag control module information. For these manufacturers, when owner permission was obtained, and the manufacturer indicated the potential availability of the data, the module was harvested from the vehicle and forwarded to the manufacturer for data retrieval, thus slowing down the case completion process.

Although manufacturers have different names for their air bag control modules, NHTSA refers to them generically as event data recorders (EDR). Throughout this paper the term "EDR" is used even though a specific manufacturer may use another name to identify their module.

VEHICLE MANUFACTURERS

Since the implementation of the CAC compliant vehicles in 2003, SCI has commenced investigations on over 100 cases. Due to the various stages of completion of active investigations, this paper utilizes the data from seventy-one (71) of the SCI cases.

These cases were either complete or nearing completion, thus would soon be available to the public via the NHTSA website. The breakdown of the manufacturers is indicated in Figure 1.

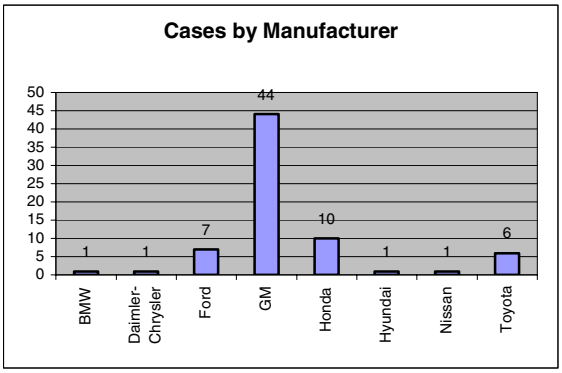

Figure 1: CAC cases by manufacturer investigated in the SCI Program as of December 31, 2004.

As Figure 1 indicates, 44 of the 71 cases (62%) were General Motor's products. Out of the eleven models that were introduced this first year, nine models were from General Motors, thus the high proportion of their products in our data. Additionally, a commercially available product that permits downloading of the air bag control module for General Motors and certain Ford products was available to all our field investigation teams.

Figure 2 indicates the types of vehicles involved in the 71 CAC cases investigated thus far in SCI cases.

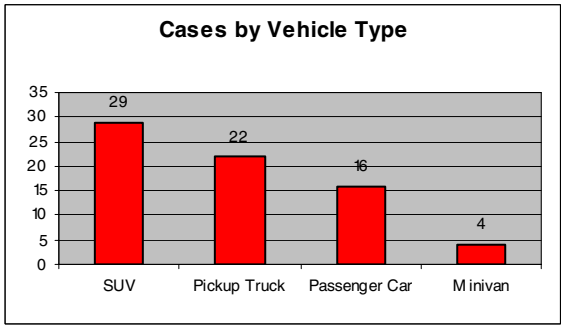

Figure 2: CAC cases by vehicle type investigated in the SCI Program as of December 31, 2004.

Manufacturers generally deployed this advanced technology in their pickup and sport utility line. These two vehicle types accounted for 51 of the 71 (72%) cases investigated by the SCI program. A key reason SCI sought out pickup trucks in these crashes was their propensity to not have a rear seat for a child occupant. SCI attempted to obtain as many cases as possible where a child was present in the right front seat. However, only two occupants age twelve and under were seated in the right front seat in the selected cases. In addition, one child aged twelve and under was seated in the center front seat in the selected cases. Even though certified advanced air bags must pass numerous performance standards, NHTSA continues to advise that children 12 and under to ride in the back seat of an air bag equipped vehicle. Minivans accounted for only four of the 71 cases. As the vehicle fleet nears 100 percent compliance to the new FMVSS certified advanced 208 standard, we expect to see a more even distribution of vehicle types investigated in the SCI cases.

CRASH SEVERITY AND CONFIGURATION

Figure 3 shows the impact configuration of the 71 CAC cases investigated.

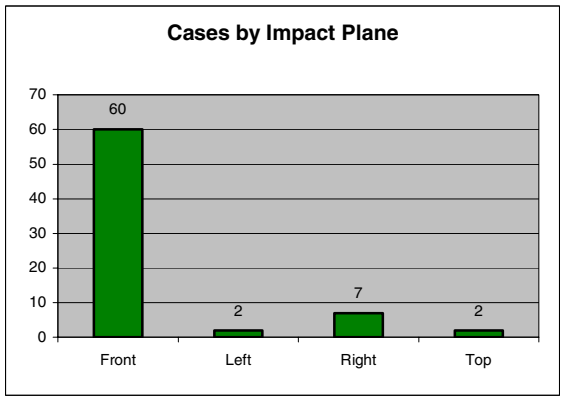

Figure 3: Impact configuration by impact plane in CAC cases investigated in the SCI Program as of December 31, 2004.

As mentioned earlier, SCI was specifically looking for "near frontal" crashes for this study. Single and multiple event crashes were included in this data collection effort. The impact plane detailed here is based on the most severe event in the crash. Therefore the large majority of investigated cases were classified as Front (60 cases / 84%). Right and left side impacts totaled nine cases (13%) combined. Two rollover (Top) cases were also included in the study making up 3% of the cases. Rear impacts were specifically excluded from the CAC program.

Figure 4 indicates the crash severity level of the case vehicles based on total delta V. Only cases where a Delta V was calculated are included in this breakdown. SCI attempted to investigate cases that had the propensity for a high-speed delta V; however,

minimal cases were identified through our network of resources.

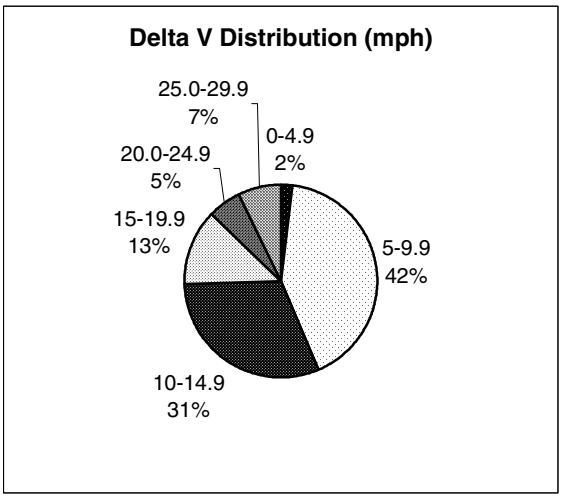

Figure 4: Crash severity distribution as measured by Delta V in CAC cases investigated in the SCI program as of December 31, 2004.

Almost three-quarters (73%) of the case vehicles inspected fell into the low to moderate range of 5-14.9 mph. One-quarter (25%) fell in the moderate to severe range of 15-29.9mph.

Total Delta V was calculated using the WinSmash algorithm; the standard reconstruction program used in NHTSA field crash data collection efforts.

CASE OCCUPANTS

Figure 5 gives the demographics of all of the front seat occupants included in the CAC program.

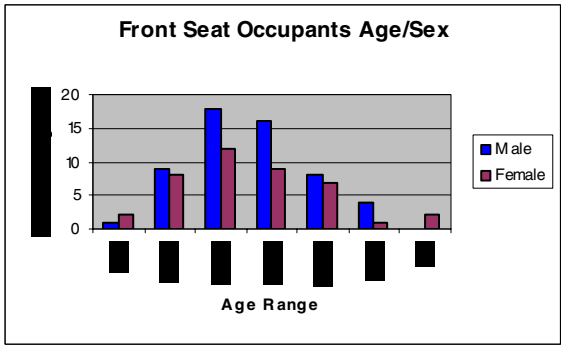

Figure 5: Front seat occupants demographics in CAC cases investigated in the SCI program as of December 31, 2004.

A total of 97 occupants were present in the front seats of the CAC case vehicles. Ages ranged from six to 84 with a median age of 34 and a mean age of 37.5. Males made up 58% of the study population; females 42%. Children aged 12 and under and adults aged 65 and over accounted for 4% each of the case occupants.

Figure 6 shows the seating positions of all front row occupants in the 71 case vehicles.

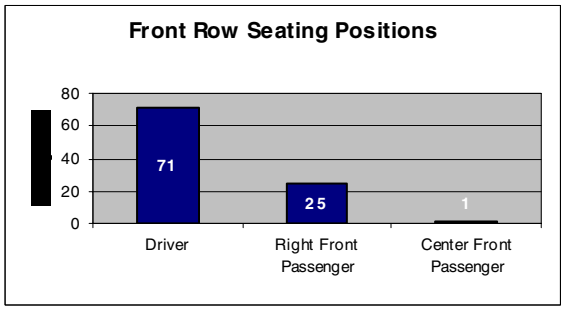

Figure 6: Front row seating positions of case vehicle occupants in CAC cases investigated in the SCI Program as of December 31, 2004.

In 45 of the 71 vehicles (63%) of the CAC cases investigated, there was a driver only (no other occupants) in the case vehicle. In 25 of the 71 case vehicles a front right passenger (35%) was present. In one case vehicle a front center passenger (1%) was present. Since the CAC vehicles are designed specifically to protect front seat occupants, rear seat occupants were not included in this breakdown.

Figure 7 indicates the belt usage for front seat occupants of the case vehicles.

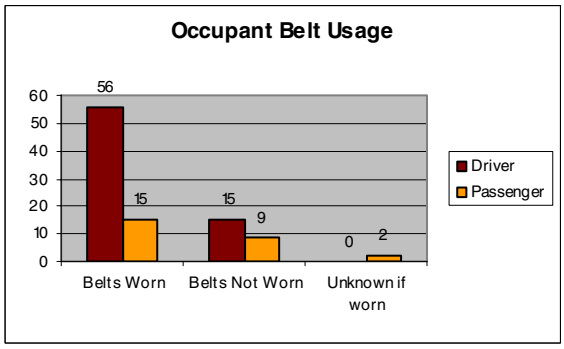

Figure 7: Safety belt usage of front seat occupants in CAC cases investigated in the SCI program as of December 31, 2004.

Of the 71 case vehicle drivers investigated in the CAC program, 79% (56) were using their available manual restraint while 21% (15) were unrestrained. Of the 26 front seat passengers, 58% (15) were using the available manual restraint; 34% (9) were

unrestrained, and the safety belt usage could not be determined for 8% (2) of the occupants. There were no occupants restrained in child safety seats in the study.

Safety belt usage is of particular interest in CAC systems because certain manufacturers configure the air bag deployment levels (stage 1 or stage 2) to the belt usage status of the front seat occupants. Therefore, the belted occupants would generally require a higher severity crash for the air bag deployment threshold to be met. Typically the air bags deploy at a lower Delta V threshold for unrestrained occupants. This can create instances of asymmetrical deployments where one front air bag may deploy while of other front bag may not.

OCCUPANT INJURY LEVEL

Figure 8 shows the injury distribution among all front seat case occupants.

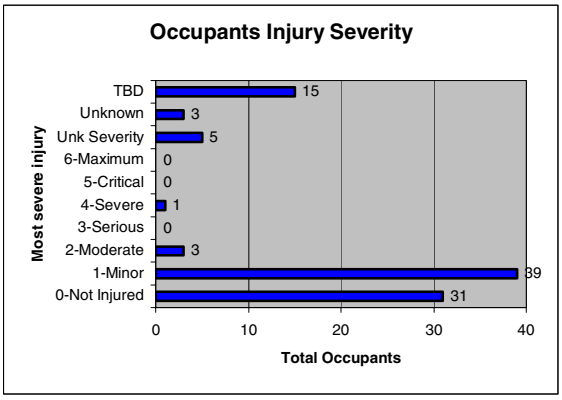

Figure 8: Most severe injury sustained by front seat CAC case occupants investigated in the SCI program as of December 31, 2004.

Of the known injury severities (Not Injured to AIS 6) the vast majority 95% (70 out of 74) of front seat occupants in the CAC vehicles sustained minor or no injuries. Only four front seat occupants (5%) sustained a moderate or higher severity injury.

In the first of these four cases a 2003 GMC Yukon was involved in a "moderate" severity rollover. The 23-year-old female driver was not using the manual lap and shoulder restraint. During the rollover sequence the driver was fully ejected from the vehicle. Her most severe injury was an AIS-4 (severe) concussive head injury which was due to her head contacting the ground.

The second case was a high severity frontal impact involving a 2003 Chevrolet Tahoe. The Delta V was calculated to be approximately 25 mph. The 32-year-old female driver was restrained by the lap and shoulder restraint. She sustained an AIS-2 (moderate) right fibula fracture attributed to loading of her foot with the floor pan.

The third case involves a front impact and a series of rollover events in a 2003 Chevrolet Tahoe. The vehicle struck a guardrail with the front plane, then rolled over, end-over-end, and struck a concrete bridge abutment with the back plane. The driver was a 37-year-old restrained female. Her most severe injury sustained was an AIS-2 (moderate) cerebral concussion. This was attributed to contact with the left roof side rail during the rollover sequence.

The final case involves a 2004 Cadillac Escalade striking two trees with the front plane. The first impact produced a longitudinal Delta V (-6.4 mph EDR recorded) high enough to deploy the driver's air bag. The tree fractured and the vehicle went on to strike another tree producing a much higher longitudinal Delta V (-33.3 mph EDR recorded). The 67-year-old male driver was restrained, however he reported that he used two plastic clips on the shoulder belt to induce approximately 2-3" of slack into the belt system for reasons of comfort. This slack may have allowed for further forward movement of his torso than would normally be expected. This along with the air bag deploying during the lower severity impact contributed to his injury. The most severe injury sustained was an AIS-2 (moderate) rib fracture.

Out of the 97 total case occupants, the injury level has yet to be determined for fifteen occupants, and eight occupants had either injuries of an unknown level or it was not be determined if they were injured.

EVENT DATA RECORDERS

Case selection was at least partially biased towards vehicles with Event Data Recorders (EDR's) that were downloadable by our field investigators. As mentioned above, this created an over representation of General Motors vehicles. With the help of other manufacturers SCI was able to also harvest EDR's from some non-GM vehicles and ship them to the manufacturer to be read. The information from the manufacturer was included in the case data with respect to the information that was recorded.

Figure 9 shows the number of EDR's successfully downloaded.

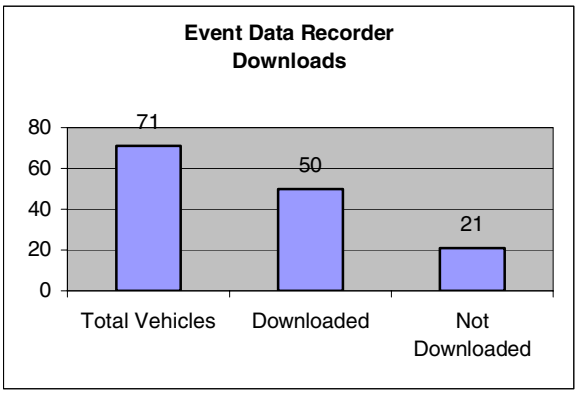

Figure 9: EDR's downloaded in CAC cases investigated in the SCI Program as of December 31, 2004.

EDR's were downloaded successfully, by either field staff or by the manufacturer, 70% of the time (50 out of 71). The information provided by the EDR (or the manufacturer) was included and coded into the SCI case data.

The 30% (21 out of 50) that were not downloaded were due to manufacturers indicating that there was no recorded information stored in their EDR, the manufacturer was not able to download the information, or in some cases, because of damage to the unit itself.

An important piece of data retrieved from the EDR's is the deployment level of the air bags. This deployment level indicates which stage of the dual-stage air bags deployed. A breakdown of air bag deployments is indicated in Figure 10 below.

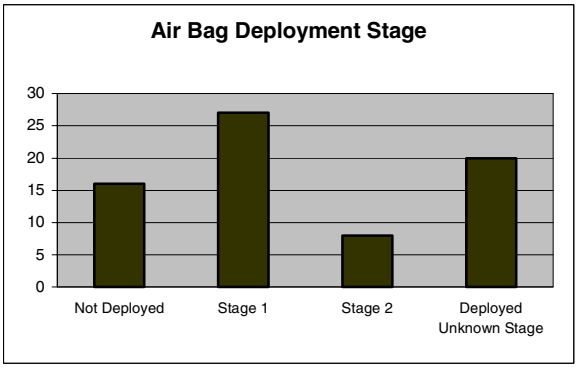

Figure 10: Driver's front air bag deployment stage in CAC cases investigated in the SCI Program as of December 31, 2004.

As indicated in Figure 10, there were a total of 71 CAC vehicle cases investigated for this paper. Of those 71 vehicles, 55 vehicles had a deployed air bag in the crash. By interrogating the EDR module, it was determined that 27 of the 55 (49%) had an air bag deployed at "Stage 1". Eight of the 55 air bags (15%) deployed at "Stage 2". The remainder, 20 out of the 55 deployments (36%) were not known as to which stage the air bag deployed because no interrogation or downloading of the air bag control, module or EDR was able to be performed.

SUMMARY

The ability to download the event data recorder is the most effective method to observe and/or measure and confirm the performance of CAC Safety System Features. In addition, EDR information is the only way our field investigators can determine what stage the air bag was commanded to deploy. Engineers and researchers are finding this piece of information extremely useful in crash analyses.

Certified advanced 208 compliant air bags appear to offer adequate occupant protection in the cases investigated thus far in NHTSA's SCI program.

In the 71 cases investigated in SCI for this paper, there were no serious or fatal injuries related to the deployment of a certified advanced compliant air bag.

As indicated in Figure 7, the safety belt usage rate for drivers in these anecdotal SCI cases is 79%. This percentage is consistent with recent safety belt information gathered in NHTSA's National Occupant Protection Use Survey (NOPUS) for 2004.

NHTSA's SCI program will continue to monitor certified advanced 208 compliant vehicles to assure adequate real world crash performance.

SCI DATA AVAILABILITY

Since 2001, SCI summary tables have been published quarterly on the NHTSA's Internet web site at the following web address:
http://www-nrd.nhtsa.dot.gov/departments/nrd-30/ncsa/SCI.html

The SCI online data access page is located at:
http://www-nass.nhtsa.dot.gov/BIN/logon.exe/airmislogon

Within the NCSA website http://www-nrd.nhtsa.dot.gov/departments/nrd-30/ncsa/.

The interface (Figure 11) is a data filter that offers users a wide array of choices when querying the SCI

Figure 11: NHTSA World Wide Web Query Interface for SCI cases.

database. For specific case access, the most efficient method of retrieval is to use the **SINGLE CASE SELECTION** by entering the Case Number (upper-case may be required) and clicking "Get Case". For a wider selection of cases, the user can use the pull down filters under the **MULTIPLE CASE SELECTION BASED ON FILTER CRITERIA** section. Users can choose to see cases by entering parameters from one or more selection criteria areas:

CASE TYPE – This selection is based on the type of case such as: Child Safety Seat, School Bus, Side Air Bag, etc. Using this selection criteria and no other will return the most cases for the selected type.

VEHICLE - Provides a selection method for limiting the output case list based on vehicle model and year make. Year make can either be a range or a single year. The parameters in the section can be used independently of the other selection criteria areas.

CRASH – A multi-filter selection area that allows the output case list to be more specific based on year, state, month and/or mortality. The parameters in the section can be used independently of the other selection criteria areas.

OCCUPANT - A multi-filter selection area that allows the output case list to be more specific based on where the occupant was located in the vehicle (role) and some physical characteristics (sex, age, and height). These parameters can be used independently of the other selection criteria areas.

As a general rule for using data filters, the fewer parameters used will mean a greater return of qualifying data, in this instance more cases. Additionally, the use of more than a few parameters can mean that the query becomes too granular and the results could be less data (cases) than expected. The best practice is to perform several practice retrievals using a variety of parameters until the right blend of parameters provides the desired results.

Complete reports can also be obtained at the address below. The reports contain images and accordingly there is a cost associated with reproduction of the crash report.

Marjorie Saccoccio, DTS-44
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Kendall Square
Cambridge, MA 02142
USA

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REFERENCES

1. Chidester, Augustus, and Roston, Thomas, *Air Bag Crash Investigations*, 17th Enhanced Safety of Vehicles Conference 2001; U. S. Department of Transportation, National Highway Traffic Safety Administration