Electronic Crash Sensing In Air Bag Litigation

By John Rowell

Air bag litigation is particularly subject to the effects of rapidly changing technology.

The ability to detect and identify a collision is the most difficult and critical function of an air bag system. A large percentage of air bag injuries can be traced to deficiencies in the sensing system. The most significant technological changes in air bag systems are occurring in the area of sensors.

1. The Focus of The Dual Stage Deployment Debate Has Changed

Automakers initially claimed that dual stage air bags were not included in 1990 -1999 model year vehicles because such a system was not technologically feasible. This claim was made in spite of the fact that GM produced a dual stage system in 1973 with its Air Cushion Restraint System (ACRS). The ACRS utilized an augmented inflator which stored inert gas compressed in a pressure vessel. In litigation in the 1990's, the manufacturers attacked the ACRS as being unreliable. The companies floated several arguments in support this claim. Briefly, they claimed that:

a. The pressure vessel leaked.
b. The ACRS was too powerful.
c. The bag was too big.
d. The bag was too heavy.
e. It caused too many injuries.
f. It required more than one ignitor.

However, the manufacturer's documents proved that by 1990 and 1991 old ACRS modules had been acquired and test deployed. In 1991 Ford noted that the inflators were "quite reliable". However in 1998, its designated witnesses were still testifying under oath that they were not reliable.

The arguments about the size, power and weight of the bag did not negate the viability of dual inflation technology. The size and power of the ACRS bag were not integral to deployment. Instead, these parameters were dictated by GM's attempt to make the passenger side bag large enough to protect both the right and center seat occupants. Also, in an effort to reduce underride, the bag included an inflatable knee bolster. The larger bags required more force to deploy. However, the automakers did not incorporate either center seat or knee bolster protection in their 1990's air bags. Likewise, the heavy ACRS bag material was not a requirement, it was simply what was available m the 1970's. The automakers could have incorporated a dual stage inflator with today's bag material.

The claim that the dual stage inflator caused injuries is disingenuous. The automakers knew (and their internal documents demonstrate) that most injuries were caused by the bolster which dual stage inflation would not affect.

Finally the claim that a dual stage inflator required more than one ignitor is not an argument against the technical feasibility of the system. It is an argument about cost.

Moreover, the auto industry's real world conduct demonstrated its litigation positions were not well taken. Augmented inflators were placed in several 1994 production models, including Chrysler minivans. However, Chrysler failed to utilize the augmented inflators' ability to provide dual inflation capabilities. When Ford finally got around to introducing a multistage air bag system with the 2000 Taurus, it utilized an augmented inflator and more than one ignitor.

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Automakers appear to have abandoned the claim that the inflators were not feasible. Deposition testimony in the last three years has produced admissions that the augmented inflator was in fact technologically feasible in the 1990's.

The manufacturers now defend these cases by asserting that dual stage air bags were not feasible because crash sensing for different levels was not possible in the 1990's.

Obviously, vehicles produced after 2000 are easily vulnerable to attack if they don't have multistage air bags. However, for air bag induced injuries in pre-2000 vehicles, where staged inflation is the alternative design theory, proof that dual level deployment was possible in the 1990's will be key.

2. Crash Sensing In Dual Level Systems

There are two basic methods which have been employed in dual stage inflation systems:

a. Electro-mechanical sensors as adapted by GM for the ACRS.

> GM simply installed 2 electro-mechanical sensors, one set for each deployment threshold. When the first one closed, it deployed the lower power stage and when the second one closed, it deployed the second stage. This method did work. However, electro-mechanical sensors have limitations. Electromechanical sensors do not provide informational output. They are simply electrical switches which "turn on" at a specific Delta V. The switch allows current to pass ultimately to the air bag ignitor (squib) to blow the air bag.

b. Electronic crash sensors.

Electronic crash sensing affords the best solution to providing the sensing capabilities required by a sophisticated multi-stage air bag system. I use the term multistage or multi-level inflation instead of dual stage because some systems introduced in 2000 - 2001 have at least three levels of inflation power. The sensors for today's multistage inflators are electronic.

Electronic Sensors are a combination of several components. One of the components is an accelerometer which provides a continuous stream of data to a Central Processing Unit (CPU). There are several types of accelerometers in use (e.g., piezoelectric, micro machined). They constantly measure acceleration. The signal generated by the accelerometer is sampled by the CPU. This data is then plugged into algorithms programmed into the CPU. Additional data is provided by a clock. Values are derived from this data and compared with stored values developed in crash testing. Those stored values describe various crash conditions which require an air bag to be deployed. When the values from the algorithm match those which are stored, the air bag is deployed.

The capacity to provide continuous data output makes the accelerometer ideal for multi-stage inflation, because it can identify the entire course of deceleration of the crash event, measuring each level of deceleration.

The multi-stage systems being installed since 2000 are based upon electronic sensors. This being the case, proving that electronic sensors were capable of deploying an air bag at different thresholds is the best route to proving that earlier models could have had multi-stage deployment.

3. In the 90's Electronic Sensors were capable of providing the sensing necessary to implement multistage air bags.

Electronic Sensors are comprised of components which were available throughout the 1990's. Inexpensive, high quality CPU chips, accelerometers, memory chips, timers were all off the shelf items. The algorithms are written in "C" and, of course, "C" has been in use since the early 1970's.

A single stage system with an SPS and an augmented air bag could become a dual stage system with few hardware changes. A second squib and additional gas generate (heating element) physically separated from the original generate, can convert augmented air bags into

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dual stage systems. The addition of an accelerometer to constantly provide data to a CPU would present no serious problems. And, of course, the CPU's available in the 1990's could have been programmed to direct current to a second squib.

In fact, the Mercedes and BMW sensors (Bosch) of the 1980's did discriminate between different thresholds. These systems utilized sensors and a CPU to analyze data from the sensors. The sensor used was an accelerometer. These systems were capable of and were employed to deploy multiple devices based upon different thresholds. The Mercedes system, introduced in Europe in 1982, offered as an option in the United States in 1984, and included as standard equipment in 1986, was able to send deployment current to one driver air bag squib, two passenger side squibs and a pretensioner squib. See "The Daimler-Benz Development of a Final Production Air Bag System for the U.S.A.", Hans Scholtz, 1980. The 1984 -1989 Mercedes systems could deploy an air bag, a pretension device, or both, depending on crash severity. The pretensioners were deployed by detonation a squib. See "Mercedes - Benz SRS Operation and Diagnosis -1984 thru 1989." Instead of being connected to a pretensioner squib, the system could have been connected to the squib in a second level of a multistage air bag.

In both of these systems, detonation of the squibs was determined by level of deceleration time period. In other words, the sensing system was essentially the same as those now used to deploy the 2000 multilevel air bag system.

4. Electronic Sensors have been utilized in many US market vehicles since 1994.

Automobiles with Electro-mechanical sensors are getting old and will be disappearing from the streets. Soon we will be dealing with a population of cars which is almost entirely controlled by Electronic Sensors.

Electronic Sensors can provide the capability to suppress the deployment of an air bag which would otherwise deploy late. Experts are available who will testify that an Electronic Sensor could prevent deaths and injuries to occupants who have moved close to the air bag due to slow crash events (e.g., under rides, angles, trailers, ball hitches, braking). Utilizing time and accelerometer values allows the CPU to determine whether deployment should be suppressed in a late developing crash even though the threshold is ultimately exceeded.

Electronic Sensors are admittedly better suited to deploying pretension devices than Electro-mechanical sensors.

Further, Electronic Sensors can be programmed to recognize numerous crash scenarios *if the automaker properly utilizes their capabilities.* To do so the automaker must perform enough crash tests to develop a crash data library that is representative of real world experience.

5. Electronic Sensor operation.

As pointed out above, systems which do not employ an electronic sensor(s) are inadequate. However, all systems which use Electronic Sensors are not equal.

a. Single Point Sensors.

"Single Point Sensor" (SPS) systems employ Electronic Sensors at a single location in the passenger compartment. However, Electronic Sensors are not inherently limited to a single location. On the contrary, Electronic Sensor performance is optimized when electronic sensors are used in more than one location in the vehicle. For example, according to its internal documents, Ford tested several combinations of sensor types and distributions and concluded that the best system was one which utilized two front end electro-mechanical sensors with an Electronic Sensor (Bosch) located in the passenger compartment. According to Ford, one of the worst performers was a SPS located in the passenger compartment.

If an SPS system is located in a protected area (i.e. the passenger

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area) it is susceptible to delayed deployment because it will receive the crash pulse later than a sensor located in the front crush zone. Additionally, the crash pulse will be weaker, with less amplitude and frequency information. This reduces the information available to the CPU, making discriminating between different types of crashes difficult. See Breed, David S., Sanders, T., Castell, V., "A Critique of Single Point Sensing" (1988 SAE Paper No. 980649).

Automakers will eventually admit in discovery that the selection of a SPS is influenced by the ability to reduce cost (no front sensors, fewer and smaller electrical harnesses). An automaker can save between $0.75 to $2.00 for each squib it can omit from its system. The manufacturers use accelerometers at numerous locations during crash testing to determine the crash pulse at each location. There is no reason why accelerometers cannot be utilized in the front end crush zone, providing continuous data to a CPU/sensor unit in the passenger compartment.

Ford Motor Company's model year 2000 Taurus dual level air bag system uses micromachined accelerometer sensors (made by Analog Devices, Inc.). This system utilizes a passenger compartment CPU incorporating an accelerometer in conjunction with a front end mounted satellite accelerometer. This system is different from others now in operation which rely on a SPS controlled system.

b. Not all systems utilizing an Electronic Sensor are created equally.

Ching-yao Chan in his book "Fundamentals of Crash Sensing in Automotive Air Bag Systems" (2000, University of California Press), has detailed several differences in the types of algorithms available to manipulate the data received from the accelerometer.

From information developed on several fronts, GM utilizes a derivative of the acceleration signal known as "Jerk." Jerk is used to discriminate between such events as a pothole bump (curb hit) and a collision with an automobile. In a crash test series, a vehicle is run over a curb and the accelerator output recorded. Although it may momentarily record a sharp spike that resembles the beginning of a collision, it quickly ceases. The output is incorporated into the algorithm for that sensor. During real world operation of a vehicle, a curb strike will produce an acceleration signal, which after being read by the sensor's algorithm, is identified as being an event that does not require a deployment. If a company's algorithm does not properly incorporate this type of filtering its performance may be inappropriate and cause or fail to prevent injury.

Additionally, an SPS is subject to dangerous delay in the time it takes for the crash signal to reach it. Automakers must find a way to transmit the signal quickly to the sensors. (This can be accomplished by stiffening the route to the sensor, e.g., welding the model case to the tunnel.) Additionally, different models of the same platform often have variations, some of which can be significant to the crash signal received by the SPS sensor. The 1994 Mazda MX6 is the same platform as the Ford Probe. However, each company took its own course on marketing the car. Ford chose to emphasize the "feel of the road." It provided a stiffer ride for the Probe. On the other hand, Mazda opted to sell a "smooth ride" for the MX6. The passenger compartment had a softer suspension. Several manufacturers have more expensive models of the same platform. However, if they also utilize an SPS, the question arises as *to which configuration was used in developing the sensor algorithms.* If the automaker failed to develop algorithms specifically for each model, there are potential problems.

Another example in differences between various manufacturers is the type of accelerometer used. Some manufacturers use single axis accelerometers, while others use dual axes. An accelerometer is designed to measure acceleration in one direction. Accuracy drops off dramatically for forces which operate on it from any other direction. Orientation of the accelerometer will therefore have a significant effect on its performance.

Some automakers utilize piezoelectric accelerometers, others

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use micro-machined accelerometers. Differences in these devices can also result in differences in performance.

Accelerometers are also subject to accuracy degradation due to temperature variation (temperature drift). Temperatures in the range in which the accelerometer is expected to operate in a passenger vehicle may have this effect. Inquiry must be made into the method (if any) by which the manufacturer has addressed this phenomenon. Methods used to minimize degradation include fans, large vents and use of an algorithm to re-calibrate the device.

6. Discovery Goals related to Electronic Sensors.

Determine the sufficiency of the crash data library. The manufacturer must have performed a sufficient number of crash tests to enable it to develop the profile of as many reasonably predictable real world crash events as possible. The failure to do so will leave gaps in its ability to identify whether a specific crash requires air bag deployment. For this reason, all crash tests results and reports should be obtained. If a client is injured in a predictable real world crash for which the automaker did inadequate crash testing, this should be a prominent target of your case.

Determine the difference in performance between front end sensors and passenger compartment sensors. As stated above, accelerometers are utilized in crash testing at numerous locations for the purpose of determining the crash signal at each location. These are usually performed very early in the crash test series. Comparing the data received by a tunnel mounted accelerometer with one located in the front (e.g., radiator support) will prove the time delay and signal corruption at the different location.

Determine at what point in the crash testing series performed by the manufacturer were the last significant changes made to the air bag system. This includes determining:

a. When the tank test results were last changed.
b. When did the gas generated deployment last change? (Could be material, shape, size, amount, surface expansion or decrease or combinations thereof.)
c. When did the algorithm last change?
d. When did the position of sensor module last change?
e. When were accelerometers last changed? (Could be type, number, orientation.)
f. Did the deployment path change?
g. Were tethers added or removed?
h. When was crash pulse path last changed?
i. Other factors. (Could include bag fold, bag material, shape.)

Once you have identified where each and every one of these changes, if any, were made, you will know the true extent of the crash library. Crashes after that data is finalized are either to verify the established design or to test other matters (windshield, bolsters, fuel integrity, etc.). Don't let the manufacturer take credit for a larger crash library than actually existed.

Determine the criteria for deployment utilized by the sensor. This would be valuable in allegations involving non-deployments, inadvertent deployments and delayed deployments (e.g., under what conditions does it suppress deployment.)

Identify all of the suppliers of the significant components of the sensor. The sensor manufacturer is no longer enough. These suppliers include the manufacturer of the accelerometer, the CPU chip, and any memory chip. This is necessary because some manufacturers destroy or claim to nave lost performance information on these components. At the same time, these manufacturers will claim that the components may not have had the performance characteristics needed to analyze dual deployment input or to control deployment output necessary to deploy a multilevel inflation system.

Identify the performance of the critical components. Is the accelerometer a single axis or dual axes model? How is it oriented? Is it temperature compensated? How? How fast is the CPU? What programming language was used?

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What is its Input/Output capacity?

Obtain the schematics of the sensor and its circuit board. These will supply valuable information about the components, and of the number and nature of connector pins (utilized and un-utilized.)

Obtain comparative testing of sensor systems. A well-run program should include testing (if any) performed by the manufacturer (or its supplier) of different combinations of electronic and electro-mechanic sensors in distributed and non-distributed systems.

Obtain design and verification testing for the manufacturer's non-electronic sensor products. These may prove that the electro-mechanical systems have a quicker response due to front crash sensors. This would be helpful in delayed deployment cases.

Algorithms. In order to criticize the algorithm, it would be useful to have it. This will be hard, since it is likely to be proprietary to the supplier. If it is suspected that a poorly designed algorithm is a factor in an injury, every effort must be made to require it to be disclosed. As vehicles without electronic sensors begin to go out of service, pressure will increase to examine the algorithm more closely.

Supplier Contracts. The manufacturer may claim that it cannot obtain vital information about the sensor (testing, design, performance) because they are the product of the supplier. These contracts define the relationship between the supplier and the manufacturer. In the past these contracts have revealed suppliers duties to provide documents to the manufacturer upon request and to provide testimony to defend the product in lawsuits.

7. Reference Material

Excellent reference material for accelerometer technology can be found at manufacturer's web sites. Analog Devices Inc. maintains a web site (www.analog.com) which has a large amount of useful information on accelerometers. This includes a tutorial, product descriptions, descriptions of the manufacturing process, schematics, applications, design tools and performance details. Visit the Bosch site regularly.

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