# The Story Behind **Defective Airbags**

*By Brian Rohrig*


IN THE SPRING OF 2016, A 17-YEAR-OLD HIGH SCHOOL senior from Texas had a minor collision with another vehicle. She was driving a 2002 Honda Civic when she rear-ended another car. Even though she was only traveling at 15 miles per hour, the impact was forceful enough to activate the airbag in her car.

The airbag expanded with too much force, rupturing a metal canister that was part of the airbag. Tragically, a piece of jagged metal shrapnel from the exploding canister pierced her neck, severing an artery. She died shortly afterward.

Sadly, this teen was one of at least 20 people known to have died from defective airbags manufactured by the Takata Corporation of Japan. At least 200 more people have also been injured by defective airbags.

Most of these casualties have occurred in the United States, resulting in the recall of more than 40 million vehicles since 2001 so far—making it the largest auto safety recall in history. And that number is expected to rise to 65 million or more. While Hondas were most affected by the recall, vehicles made by Toyota, Ford, General Motors, and other carmakers were affected as well. As of December 2017, about 20 million airbags had been replaced, leaving millions of defective airbags in vehicles still on the road.

## How airbags save lives

Reports show that thousands of lives have been saved by airbags. In short, here's how they protect people in a crash: When a car stops suddenly, the bags inflate rapidly, softening the impact that your body experiences.

But you don't want an airbag deploying every time you slow down, or in a minor collision when cushioning isn't necessary. So airbags are equipped with a sensor that detects a rapid deceleration. Older airbags use a mechanical sensor system that involves a metal ball connected to either a spring or a magnet. When you slam on the brakes, the ball breaks free and activates an electronic

VEHICLE ILLUSTRATION © GRAHAM MURDOCH; SHELLEY RUSSELL; ISTOCK sensor. Newer airbags contain much more sensitive electronic accelerometers contained within a microchip.

As soon as a car stops suddenly, the airbags inflate. Many people assume that a tank containing air at high pressure releases its contents to blow up the airbags. But this method would be far too slow. Airbags are actually inflated by a very rapid chemical reaction (Fig. 1). A car's sensor sends an electrical signal to the detonator, which initiates a chemical reaction that inflates the airbag.

To provide adequate protection for the occupant of a vehicle involved in a crash, the airbag must deploy in 40 milliseconds or less. So the chemical reaction that triggers the airbag's inflation must happen extremely fast.

Immediately after inflation, the airbag starts to deflate, as the gas escapes through tiny pores in the fabric. It is crucial that the head or torso hit the airbag as it is deflating, not inflating, as a fully inflated airbag would not provide enough of a cushion to protect the occupant. Contact with the airbag generally occurs about 50 milliseconds after a collision, allowing time for the airbag to begin to deflate.

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### How airbags can keep you safe

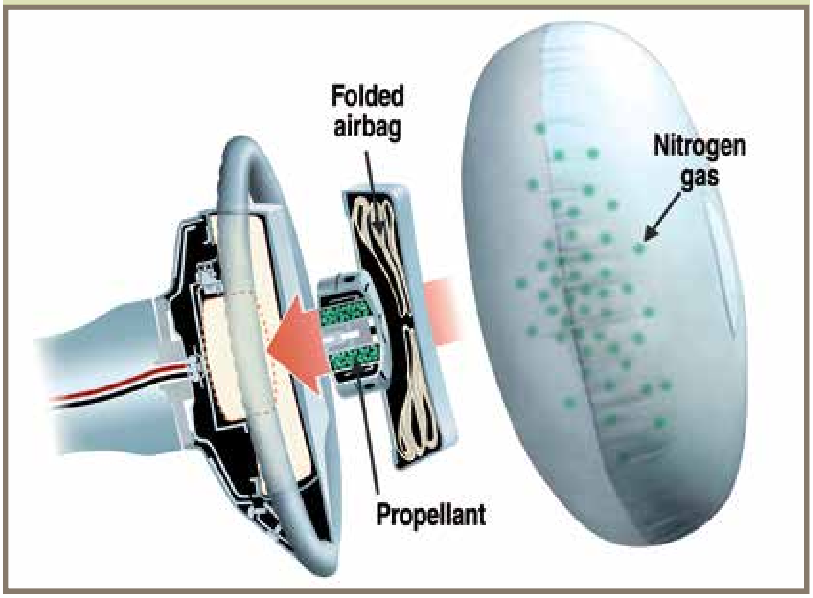



**Figure 1. In a crash, a detonator ignites the propellant (green pellets), causing it to break down and release a burst of nitrogen gas. The reaction inflates the airbag in less time than it takes you to blink an eye.**

## Defects aside, working airbags save lives.

Frontal airbags reduce fatalities by **14 percent** when no seat belt is used, and by **11 percent** when a seat belt is used.

In 2015, frontal airbags saved an estimated **2,573 lives**. Between 1987—when airbags first began to be installed in vehicles—and 2015, an estimated **44,869 lives** were saved.

SOURCE: NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

## Seeking the right reaction

Older airbags contain solid sodium azide ($NaN_3$). Sodium azide is very stable at low temperatures, but it decomposes at temperatures above 300 °C. When the airbag is triggered, the detonator sends an electrical impulse that generates enough heat to initiate the decomposition of the $NaN_3$. The products of this reaction are solid sodium and nitrogen gas. The reaction is as follows:

$$2\ NaN_{3(s)} \rightarrow 2\ Na_{(s)} + 3\ N_{2(g)}$$

Solid sodium is not a product you want to have left over, as it reacts rapidly with water. So the airbag also contains potassium nitrate ($KNO_3$), which converts the sodium into less harmful products, including more nitrogen gas. The additional nitrogen helps to inflate the airbag further. However, the other products potassium oxide ($K_2O$) and sodium oxide ($Na_2O$) are corrosive. To make the system safer, the airbag contains silicon dioxide ($SiO_2$), which converts the unwanted by-products into inert silicate glass.

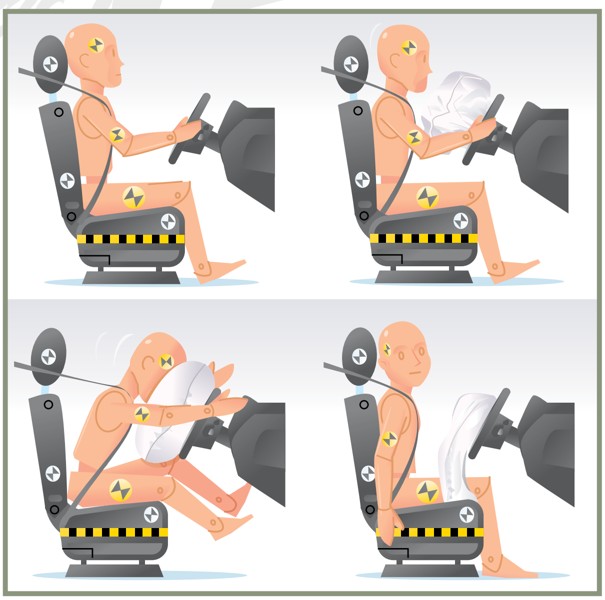
A typical airbag of this type contains 130 grams (g) of sodium azide, enough to generate 70 liters of nitrogen gas at standard temperature and pressure—0 °C at 1 atmosphere—and fill the airbag.

Although sodium azide is effective at inflating airbags, it has many drawbacks. For one, it is about as toxic as cyanide compounds. Even small amounts of sodium azide can cause serious short- and long-term health conditions.

In light of the toxicity of sodium azide, airbag manufacturers have been searching for safer alternatives. They initially made the switch to tetrazole ($CH_2N_4$), a less toxic compound. Due to the limited availability and high cost, however, Takata eventually switched to ammonium nitrate ($NH_4NO_3$), a more plentiful and cheaper alternative. When an airbag containing ammonium nitrate is activated, it thermally decomposes into water vapor and nitrous oxide ($N_2O$), which is also known as laughing gas.

## Does Your Airbag Need to Be Replaced?

**To find out if your car is affected, visit www.safercar.gov. If your car is on the list, call your local auto dealer. Even though the chances of an airbag deploying prematurely or with excessive force is extremely rare, it is better to be safe than sorry.**



## So what went wrong?

Despite the fact that ammonium nitrate is less toxic and cheaper than its predecessor, it became central to the Takata airbags' fatal flaw.

Within an airbag system, the ammonium nitrate exists in pellet form, with just the right amount of surface area to produce a reaction in the precise time period needed to inflate the airbag. The problem is that the compound is easily affected by temperature changes—which occur often under normal driving conditions—and moisture.

Theoretically, the ammonium nitrate was supposed to be protected from moisture. But recent research into Takata's defective airbags revealed a flaw in the metal inflator housing the ammonium propellant. The inflators were insufficiently sealed, allowing moisture from humid air to seep in. Exposure to humidity can cause ammonium nitrate to dissolve over time.

Changes in temperature also affect the compound, but in a different way. Cycling between hot and cold can cause the crystal structure to shift between various states, which can result in the pellets cracking into fragments. Smaller pieces have a greater surface area and produce gas faster than the airbag designers intended. This creates more pressure than the system can withstand. Instead of allowing the gas to release into the airbag, the canister explodes—in some cases, even when there's no crash.

## Fixing the flaw

Newer airbag inflators that contain ammonium nitrate now include a desiccant, or drying agent, that absorbs water. This addition is designed to keep the ammonium nitrate dry, and thus prevent it from decomposing. In July of 2017, however, Takata filed an additional recall for inflators containing one particular type of desiccant containing calcium sulfate ($CaSO_4$).

Now, most companies that manufacture airbag inflators have turned to stable guanidine nitrate—$[C(NH_2)_3]NO_3$. It reacts according to the following equation:

$$[C(NH_2)_3]NO_{3(s)} \rightarrow 3\ H_2O_{(g)} + 2\ N_{2(g)} + C_{(s)}$$

Takata also announced plans to move away from ammonium nitrate to guanidine nitrate with the goal of preventing more airbag tragedies from occurring. CM


**SELECTED REFERENCES**

Casiday, R.; Frey, R. Gas Laws Save Lives: The Chemistry Behind Airbags. Washington University, Department of Chemistry, 1998 (last revised October 2000): http://www.chemistry.wustl.edu/~edudev/LabTutorials/Airbags/airbags.html.

LaFrance, A. How Airbags Are Supposed to Work. *The Atlantic*, June 27, 2015: http://www.theatlantic.com/technology/archive/2015/06/airbags/396854.

Brain, M. How Airbags Work. How Stuff Works.com: https://auto.howstuffworks.com/car-driving-safety/safety-regulatory-devices/airbag1.htm.

Merola, J. S. How Do Air Bags Work? *Scientific American*: https://www.scientificamerican.com/article/how-do-air-bags-work.

Takata Airbag Failures Caused by Design, Chemistry, Climate. Bloomberg News, Industry Week.com, Feb 24, 2016: http://www.industryweek.com/safety/takata-airbag-failures-caused-design-chemistry-climate.

Tabuchi, H. Takata's Switch to Cheaper Airbag Propellant Is at Center of Crisis. *The New York Times*, Nov 19, 2014: https://www.nytimes.com/2014/11/20/business/takatas-switch-to-cheaper-airbag-propellant-is-at-center-of-crisis.html.

Tabuchi, H. Takata Airbag Defect Is Traced to Moisture and Temperature. *The New York Times*, May 4, 2016: http://www.nytimes.com/2016/05/05/business/takata-airbag-defect-recall.html.



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