UNITED STATES DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
1200 New Jersey Avenue SE
Washington, D.C. 20590

In re:

EA15-001
Air Bag Inflator Rupture

REPORT OF TK HOLDINGS INC. PURSUANT TO PARAGRAPH 33.a OF THE NOVEMBER 3, 2015 CONSENT ORDER

June 30, 2016

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I. Introduction

Over the past several years, TK Holdings Inc. ("Takata"), the National Highway Traffic Safety Administration ("NHTSA"), and several major vehicle manufacturers have taken actions to initiate wide-ranging recalls in the United States of vehicles equipped with Takata airbag inflators containing phase-stabilized ammonium nitrate ("PSAN"). These recalls are based on concerns that some of these inflators may rupture during deployment, creating a safety risk to drivers and passengers (so-called "field ruptures" of inflators). What began as a limited set of focused recalls and regional field actions affecting a small number of vehicle makes and models has expanded to become the largest set of automotive recall campaigns in U.S. history.

In order to promote the safety of drivers and passengers nationwide, Takata has worked cooperatively with NHTSA, world-class technical experts, and vehicle manufacturers to identify the root cause of PSAN inflator ruptures. Takata's root cause analysis has involved numerous scientific and technical experts and extensive analysis of complex chemical and environmental factors. These independent and overlapping analyses have enabled the company, safety regulators, and major vehicle manufacturers to identify relevant factors over a period of time. Based on this root cause analysis process, Takata has agreed to work with NHTSA and the vehicle manufacturers to initiate recalls and the replacement of affected airbag inflators to remedy the safety concerns relating to non-desiccated PSAN inflators nationwide, even in those vehicles and geographic areas that currently appear to pose a remote safety risk during the service life expectancy of the inflators. Takata also has funded and developed a vigorous "Get the Word Out" campaign to maximize recall completion rates and has conducted substantial consumer advertising to encourage car owners receiving recall notices to bring their cars in to dealers for prompt replacement. The company is working closely with NHTSA, vehicle manufacturers, and other airbag manufacturers to ramp up the production capacity for replacement airbag inflators and to develop new designs for non-PSAN airbag inflators.

Takata submits this report pursuant to the Consent Order entered into by Takata and NHTSA in this matter on November 3, 2015. Paragraph 33.a. of the Consent Order specifies: "Through counsel, Takata shall provide a detailed written report to NHTSA regarding the history of the rupturing inflator issues giving rise to Recall Nos. 15E-040, 15E-041, 15E-042, and 15E-043 no later than June 30, 2016." Takata initiated the enumerated recalls with the filing on May 18, 2015 of four Defect Information Reports ("DIRs") pursuant to Part 573 of NHTSA's regulations under the Motor Vehicle Safety Act. The four DIRs covered various types of driver and passenger PSAN inflators manufactured by Takata and used in vehicles in the United States. These DIRs identified a potential defect that may arise in some of these inflators as a result of a long-term phenomenon of degradation of the PSAN propellant associated with the inflators' exposure over several years to environments of high heat and high absolute humidity, in addition to the potential for manufacturing variability.

This report details the factual history of the PSAN inflators subject to Recall Nos. 15E-040, 15E-041, 15E-042, and 15E-043 and the analysis and investigation that led Takata, in consultation with independent experts, to identify the previously unrecognized and unanticipated phenomenon of potential long-term propellant degradation associated with environmental heat and humidity as the probable root cause of field ruptures observed in these inflators. It describes Takata's internal discussions and decision-making regarding the production of these inflators, including lapses that occurred in the initial testing of certain inflators for vehicle manufacturers. It also explains the extensive steps Takata has taken and committed to take in order to remedy the specific inflators under recall, to phase out the production of inflators using PSAN propellant without a desiccant material added (so-called "non-desiccated PSAN inflators"), eventually to transition to non-PSAN propellant in Takata inflators, and to ensure that potential safety issues do not go unheeded in the future. Takata's goal is to create an unparalleled product safety and stewardship program to protect its customers and drivers and passengers worldwide.

Takata has already implemented significant remedial oversight and compliance measures. As provided for in the November 3, 2015 Consent Order, it has agreed to substantial oversight by an Independent Monitor and has established processes for Takata employees to report concerns anonymously to the Independent Monitor. Takata has appointed a Chief Safety Assurance and Accountability Officer and created a Product Safety Group with authority to investigate and preemptively address safety-related issues across Takata's product lines. It is creating a data vault that will guarantee preservation and transparency of information for at least 30 years. It has implemented improved internal processes for reporting compliance concerns, educating employees about compliance policies, and identifying and escalating manufacturing and quality problems. It has commissioned an independent audit of inflator validation reports. It also established an independent Quality Assurance Panel ("QAP") with a broad mandate to review Takata's practices and policies for the safe production of airbag inflators. The QAP made 15 recommendations to improve Takata's safety processes, described in more detail below. Takata has taken affirmative steps to initiate action on all of these recommendations.

This report plays an important role in the company's assessments relating to airbag inflators by identifying the events that led to the production of PSAN inflators that may pose a safety risk to drivers and passengers. Substantial work remains to be done to implement and complete the unprecedented recalls of vehicles equipped with these inflators—recalls that will ultimately result in the replacement of all Takata non-desiccated PSAN driver and passenger inflators nationwide. This report illustrates how Takata will continue to commit itself to that work and to ensuring that safety issues of this type never recur in Takata products.

II. Executive Summary

A. *Takata begins manufacturing inflators*

In the late 1980s, Takata Corporation ("TKC"), which was founded in Japan in 1933, established Takata (*i.e.*, TK Holdings Inc.) in North Carolina. Takata is a separate corporation and a subsidiary of TKC and, since its founding, has operated the company's business in North America. Takata was primarily responsible for the development, testing, and production of the inflators at issue in Recall Nos. 15E-040, 15E-041, 15E-042, and 15E-043.

Takata's inflator manufacturing began with two joint ventures established in the late 1980s. The first was entered into with Bayern-Chemie, a German company, and was responsible for manufacturing driver inflators in LaGrange, Georgia. The second was with an entity called Rocket Research in Moses Lake, Washington, and it was responsible for designing and manufacturing passenger inflators. In subsequent years, the two joint ventures became wholly owned and operated by Takata.

In the 1990s and 2000s, Automotive Systems Laboratory, Inc. ("ASL"), Takata's research and development center in Michigan, was primarily responsible for creating inflator designs and testing to ensure the sustainability of those designs. Through Inflator Systems Inc. ("ISI"), Takata was primarily responsible for mass production manufacturing of inflators and testing to ensure their safety for use in the field. Both ASL and ISI are wholly owned by Takata. Since its inception, Takata has also conducted lot acceptance testing ("LAT") on its products, which is testing on every lot of production line inflators and airbag modules, to verify that the products were manufactured in accordance with vehicle manufacturer specifications. Throughout this period, TKC personnel have supported the design, manufacturing, and testing of PSAN inflators and have served as the primary customer contact for Japanese vehicle manufacturers.

B. *Takata develops a phase-stabilized ammonium nitrate-based ("PSAN") propellant*

In the late 1990s and early 2000s, as part of its efforts to provide customers with the most effective and highest quality airbags possible, Takata began development of airbags containing inflators that used a phase-stabilized ammonium nitrate-based ("PSAN") propellant. The use of PSAN in the propellant was new to Takata at the time, and Takata viewed its use as beneficial for a variety of reasons, including its ability to meet the performance preferences of customers without certain negative side effects associated with other propellants. Specifically, Takata's PSAN propellant was less toxic, safer to manufacture, and more gas efficient, thus allowing for smaller, lighter inflators that were more easily integrated into smaller, more fuel-efficient vehicles and vehicle interior designs while providing increased manufacturing and occupant safety.

In developing the PSAN propellant, the first formulation of which was referred to as "2004" propellant, Takata relied on an internal development testing regimen that exceeded industry standards for long-term heat aging and thermal cycling. Takata did so to investigate the physical and chemical stability of 2004 propellant and to project reliable field performance. Takata later developed a second version of the propellant called "2004L," which was combined with a desiccant material in the inflator and was designed to have lower emissions and to allow for the manufacture of even lighter and smaller inflators to meet market demands.

As a result of the advantages offered by Takata's PSAN technology, vehicle manufacturers around the world have purchased hundreds of millions of PSAN-containing airbag inflators from Takata and its affiliates since 2000.

C. *Development and initial production of the original PSAN inflators*

In 1999 and 2000, Takata first developed driver and passenger inflators with PSAN propellant and began production of three types of PSAN inflators in June 2000. These inflators were called the Programmable Smokeless Driver Inflator ("PSDI"), the Programmable Smokeless Passenger Inflator ("PSPI"), and the Smokeless Passenger Inflator ("SPI"). The final design of the PSDI inflator used a "batwing"-shaped PSAN propellant wafer.

Equipment manufacturers like Takata conduct validation tests of products, including airbag inflators, to ensure that the products meet the requirements specified by their customers, vehicle manufacturers. The design verification ("DV") tests are intended to establish that the inflator as designed meets the vehicle manufacturer's particular performance and durability specifications. The process validation ("PV") tests are intended to establish that the production process set up by the equipment manufacturer will enable the mass production of products that meet each vehicle manufacturer's particular performance and durability requirements. In short, the DV validates a prototype of the product as designed, and the PV validates the product as mass-produced on the production line.

Takata encountered difficulties during the production validation testing of the original PSDI, PSPI, and SPI inflators in 2000. As discussed more fully below, these difficulties included failures to meet certain PV specifications prescribed by the vehicle manufacturer, and in a few instances, these failures involved ruptures of inflators. The final versions of PV test reports that were provided to the customers omitted these test failures or included substituted or altered test results, as Takata commenced production of these inflators in the summer of 2000.

In the summer and fall of 2000, engineers at Takata made changes in the raw material processing of the propellant for the PSDI, PSPI, and SPI inflators. Takata completed these raw material processing changes in October 2000, and subsequent testing initiated in November 2000 and completed in the spring of 2001 indicated that the issues associated with the prior PV testing ruptures of these inflators had been resolved.

In connection with the later investigation beginning in 2014 of inflator ruptures occurring in the field, expert analysis indicated that the raw material processing issues associated with the PV testing failures in 2000 were not the root cause of the field ruptures of PSDI, PSPI, and SPI inflators produced prior to the processing changes. The analysis further found that the vehicle manufacturers' specifications for DV and PV testing of inflators do not predict the effects on the non-desiccated PSAN propellant of the long-term environmental exposure to high heat and high humidity associated with the observed field ruptures of these inflators.

D. *Early PSDI field ruptures*

In 2003, Takata learned that a driver inflator ruptured during a deployment in a vehicle in Switzerland. Takata investigated the issue and determined that the rupture was an anomaly and was likely due to the over-loading of batwing propellant wafers in the inflator. In 2005, Takata learned of a second PSDI rupture that had occurred in May 2004. The inflator could not be recovered, and Takata received only a few pictures of the ruptured inflator, which limited Takata's ability to determine the root cause of the incident. After reviewing the limited information available, Takata tentatively concluded that the incident was also an anomaly.

E. *First PSDI recalls*

In 2007, Takata learned of three PSDI ruptures in vehicles in the field. Takata and the vehicle manufacturer immediately began an investigation of the ruptures, which included testing and analysis of the relevant production lots for the ruptured inflators, as well as inflators recovered from junkyards and from vehicles returned from the field (so-called "field-returned inflators"). The inflators involved in these ruptures were manufactured between October 31 and November 15, 2000. In 2008, a fourth rupture occurred in the field. The inflator involved in this rupture was manufactured on December 1, 2000. Takata recommended that the vehicle manufacturer initiate a recall of vehicles containing inflators that came from the same production lots as the field event inflators, as well as vehicles containing "surveillance" inflators from approximately 207 lots adjacent to the event lots, which were to be tested and analyzed. The vehicle manufacturer then issued Recall No. 08V-593.

By the late spring of 2009, Takata's testing and analysis of the surveillance inflators from Recall No. 08V-593 started to indicate that some propellant wafers were of low density, which could lead to ruptures. These wafers were manufactured on a press referred to as the "Stokes" press. In addition, Takata observed an apparent pattern of propellant physical property differences associated with the practice of "recycling" propellant from other lots, during which propellant that was deemed non-compliant for dimensional (not chemical) reasons would be re-dissolved and made into a new propellant batch.

By early June 2009, Takata learned of two additional field ruptures of PSDI inflators. Based on its analysis, Takata recommended an expansion of the recall scope to cover all vehicles equipped with inflators containing (i) Stokes-pressed propellant manufactured between June 2000 and the end of February 2001, when data indicated the Stokes-pressed propellant would equal the density of the sufficiently dense propellant pressed on what was referred to as the "Gladiator" press, (ii) propellant pressed on the "Gladiator 2" press, which was associated with the production lot involved in a field rupture, (iii) propellant processed with recycled material, and (iv) propellant from approximately 1,000 additional lots of propellant produced through October 2011, for surveillance purposes. The vehicle manufacturer agreed and issued Recall No. 09V-259.

Through analysis conducted subsequent to Recall No. 09V-259, Takata and the vehicle manufacturer hypothesized that the propellant's insufficient density was caused by low compaction force on the Stokes press. Together, the vehicle manufacturer and Takata concluded that the vehicle manufacturer should recall all vehicles equipped with inflators containing propellant manufactured on the Stokes press, which was in operation from June 2000 through October 2001, and the vehicle manufacturer accordingly issued Recall No. 10V-041. The vehicle manufacturer expanded the recall further in 2011 after Takata's records showed it was possible that some Stokes-pressed propellant could have been identified as having been pressed on the Gladiator press. The ensuing Recall No. 11V-260 applied to inflators containing propellant pressed on any press while the Stokes press was in operation.

In late 2009, NHTSA requested information from Takata in connection with an investigation of the first two PSDI recalls, RQ09-004. Takata provided responses to NHTSA in late 2009 and early 2010, and NHTSA closed its investigation in 2010.

F. *Takata investigates root cause*

In 2009 and 2010, Takata conducted an investigation to attempt to determine the root cause of the field events that gave rise to the PSDI recalls, the chemistry and effects of aging on PSAN propellant, and the robustness of Takata's manufacturing process. The results of this review were consistent with the causation hypotheses that supported Takata's recall recommendations.

At the direction of one of its vehicle manufacturer customers, Takata also engaged experts from Penn State University and the University of California-Berkeley to analyze its PSDI failures. Between 2010 and 2013, these experts investigated the issue. While Takata did not disagree with the work of the Berkeley experts, which focused on analysis of the inflator body, or with much of the work of the Penn State expert, Takata did ultimately disagree in part with the Penn State expert's analysis relating to a "dynamic burning" theory, which Takata believed was flawed as applied to the Takata PSAN propellant, failed to take into account certain information, and used suspect testing procedures. The dynamic burning theory was subsequently discounted by Takata based on expert analysis by both Takata engineers and additional outside expert analysis.

G. *Initial passenger inflator ruptures and recalls*

In 2010, two vehicle manufacturers recalled certain non-U.S. vehicles containing SPI inflators after four SPI inflators ruptured during disposal in junkyards in Japan. Takata believed that the SPI events resulted from either missing propellant wafers or missing springs combined with normal vehicle aging.

In late 2011, Takata learned of two field ruptures involving an SPI inflator and a PSPI inflator. The SPI inflator ruptured in a vehicle in Japan, was manufactured in July 2001, and contained propellant pressed in June 2001. The PSPI inflator ruptured in a vehicle in Puerto Rico, was manufactured in June 2001, and contained propellant pressed in March 2001. Takata began a review of the passenger inflator ruptures, and between 2012 and 2013 posited two hypotheses it believed at the time might explain these field events. The first was the so-called "auto-reject" hypothesis, according to which a propellant press could have produced propellant that had insufficient density because an auto-reject mechanism on the press that should have automatically rejected such propellant could be manually turned off. The second was the "weekend moisture" hypothesis, which said that propellant could have been exposed to excessive moisture over weekends and holidays when it was left on the assembly line by machine operators instead of being put in climate-controlled areas. In April 2013, Takata filed DIR No. 13E-017 covering certain passenger inflators based on these two hypotheses. Six vehicle manufacturers issued recalls based on Takata's DIR. Ruptures of inflators covered by the driver inflator recalls between 2008 and 2011 and the passenger inflator recalls in 2013 came to be known as "Alpha" events.

H. *"Beta" rupture events, investigation, and regional field actions*

In August 2013, another PSDI driver inflator ruptured in the field. This inflator, which ruptured in a vehicle in Florida, fell outside the range of previously recalled PSDI inflators. The scope of the previous PSDI recalls between 2008 and 2011 had captured all prior field ruptures to that point. This rupture, which fell outside the scope of the earlier recalls and was not explained by the then-existing root cause hypotheses, came to be referred to as the first "Beta" event. Additional Beta events involving ruptures of both driver and passenger inflators occurred in 2013 and 2014.

Beginning in late 2013, Takata conducted an investigation into the cause of the Beta events. Takata again engaged outside experts to assist it in its investigation. By May 2014, Takata's analysis led it to hypothesize that the ruptures were caused by long-term exposure to high absolute humidity environments. The Beta events were occurring in U.S. locations with the highest levels of absolute humidity. Testing indicated that moisture intrusion was possible in these conditions over long periods of exposure. In June 2014, Takata advised NHTSA that it would support regional field actions to replace and retrieve inflators in vehicles sold or registered in Florida and Puerto Rico, where the Beta events had occurred, as well as two other locations with similar climate conditions. Takata's analysis, however, was yet incomplete and its investigation continued in consultation with NHTSA, vehicle manufacturers, and independent experts.

Approximately nine vehicle manufacturers conducted the regional field actions beginning in June 2014. In the fall of 2014, several vehicle manufacturers issued recalls covering certain passenger inflators in the Gulf states and elsewhere. In response to those recalls, Takata submitted DIR No. 14E-073 in November 2014.

In November 2014, while Takata's analysis continued, NHTSA requested that the company issue a DIR in support of a nationwide recall of certain driver airbags. Takata responded in early December emphasizing its commitment to the safety of the driving public, but declining to issue a nationwide DIR because Takata believed that such action was unsupported by the data available at the time. Takata nevertheless continued to work with, and provide information to, NHTSA and vehicle manufacturers as part of the investigation of the Beta events.

In February 2015, NHTSA informed Takata that it had concluded that Takata had failed to respond fully to two Special Orders issued by NHTSA and advised Takata that it would impose a civil penalty of $7,000 per day for each Special Order until Takata fully responded. Takata responded through counsel that it did not believe NHTSA's conclusion was justified in light of the substantial cooperation Takata had given and the tremendous resources it had expended in doing so. Ultimately, the parties settled the issue such that no penalties related to this issue would be levied beyond May 2015.

I. *NHTSA Consent Orders and further recalls*

While Takata's investigation continued and additional ruptures occurred in the field, Takata filed the four DIRs for Recall Nos. 15E-040, 15E-041, 15E-042, and 15E-043 on May 18, 2015 in connection with an agreement reached with NHTSA. These DIRs covered all PSDI, PSDI-4, and PSDI-4K inflators (the non-desiccated PSAN driver inflators using batwing propellant wafers) from start of production to end of production, and certain SPI, PSPI, and PSPI-L non-desiccated PSAN passenger inflators installed in certain specified makes, models, and model years of vehicles. The DIRs contemplated national recalls of these inflators. On the same day, Takata entered into a Consent Order with NHTSA. Under that order, Takata, among other things, agreed to continue to cooperate with NHTSA in its investigation and to provide proposals for implementing recalls and for testing the service life and safety of replacement inflators.

On November 3, 2015, Takata entered into an additional Consent Order with NHTSA. Under that order, Takata agreed to pay a civil penalty of $70 million by October 2020, an amount that could increase to $200 million if Takata failed to comply with certain provisions in the Consent Order. In addition, Takata agreed not to enter into new contracts for the supply of PSAN inflators for use in the U.S., to phase out the manufacture and sale of non-desiccated PSAN inflators, to conduct testing to determine the service life and safety of both desiccated and non-desiccated PSAN inflators, and to the appointment of an Independent Monitor to ensure Takata's compliance with the May and November 2015 Consent Orders. Also on November 3, 2015, Takata agreed to cooperate with NHTSA's "Coordinated Remedy Program," established by a Coordinated Remedy Order issued by NHTSA, pursuant to which vehicles would receive replacement inflators according to a schedule of prioritization to be determined under NHTSA's authority.

On December 23, 2015, NHTSA announced that it had selected John D. Buretta of Cravath, Swaine & Moore LLP to serve as the Independent Monitor. Since appointment of the Independent Monitor, Takata has worked with the Monitor and his team to facilitate his oversight of the Coordinated Remedy Program and Takata's compliance with the Consent Orders. Prior to January 1, 2016, Takata also announced the appointment of a Chief Safety Assurance and Accountability Officer ("CSO"), who works directly with the Independent Monitor and his staff. Further, in accordance with Paragraphs 33.b and 52 of the November 3, 2015 Consent Order, Takata gave notice to NHTSA on December 31, 2015 that Takata and TKC had terminated the employment of several individuals in relation to the subject matter of the Consent Order.

On January 25, 2016, based on discussions with NHTSA and analysis of further test results and field events, Takata filed two additional DIRs with NHTSA that contemplated national recalls and applied to two types of non-desiccated driver inflators not covered by the May 18, 2015 DIRs. On May 4, 2016, Takata agreed with NHTSA to an amendment of the November 3, 2015 Consent Order (the "Amendment"). In the Amendment, NHTSA stated that, in consultation with its expert Harold R. Blomquist, Ph.D., the agency concluded that the likely root cause of ruptures in non-desiccated frontal Takata PSAN inflators is a function of time, temperature cycling, and environmental exposure. NHTSA further concluded that, at some point in the future, all non-desiccated frontal Takata PSAN inflators would likely develop the potential for an unreasonable safety risk. Accordingly, NHTSA ordered Takata to submit DIRs covering all remaining non-desiccated frontal airbag inflators by three geographic zones on a schedule extending from May 16, 2016 to December 31, 2019. Takata subsequently filed three DIRs on May 16, 2016 in accordance with the terms of the Amendment.

J. *Remedial steps taken by Takata*

As a result of the investigations into Takata's PSAN inflators and Takata's consultations with NHTSA, vehicle manufacturers, and independent experts, Takata has taken numerous significant steps to improve production quality and to prevent future safety lapses and product failures. In addition to working with the Independent Monitor to ensure the company's compliance with all NHTSA directives, Takata has also enabled employees to report issues directly to the Independent Monitor through a hotline or through an anonymous reporting mechanism. It has established the CSO and is staffing the newly created Safety Accountability and Assurance Office, which reports to the CSO. A new data vault is being implemented to ensure the retention and integrity of data for 30 years, and the Product Safety Group has been established to work on potential safety-related issues for all products.

Takata has also put in place a daily meeting system and new escalation procedures such that manufacturing concerns are reported within 24 hours to the pertinent Quality Assurance personnel. Those concerns are reviewed and may then be routed to the new Early Warning System, which notifies all potentially affected manufacturing plants about the potential for similar manufacturing concerns, and/or to a Special Task Force board comprising Quality

Assurance, Sales, Engineering, and Manufacturing representatives that reviews the matter in detail. Takata also now requires that a Global Horizontal Deployment Form be filled out whenever a quality incident occurs at a manufacturing facility, and that it be distributed to managers throughout the company. Takata and a vehicle manufacturer have jointly commissioned audits of Takata's inflator validation testing reports to identify any test results that could indicate a safety problem. And in December 2014, Takata established an independent Quality Assurance Panel ("QAP") composed of experts in the industry. The QAP issued a report in February 2016 recommending various processes for Takata to implement to improve the safety of its manufacturing processes and products. Takata has undertaken to implement all of the QAP's recommendations.

III. Takata's Introduction of Phase-Stabilized Ammonium Nitrate ("PSAN") Propellants

A. *The drawbacks of sodium azide propellants*

Until the late 1990s, sodium azide was the principal oxidizer used in airbag inflator propellants. Although sodium azide inflators produced a non-toxic gas (nitrogen) during combustion, there were significant problems with the use of sodium azide in inflators. First, sodium azide has a low gas efficiency of only 40 percent, and it takes approximately 80 grams of the compound to fill a standard driver-side airbag.[1] Second, sodium azide is highly toxic in its propellant state. According to the Centers for Disease Control and Prevention, sodium azide is a potentially deadly chemical that when mixed with water or acid changes rapidly into a toxic gas.[2] Mild exposure to sodium azide can result in headache, nausea, vomiting, rapid breathing, and skin burns, and more prolonged exposure can lead to convulsions, loss of consciousness, respiratory failure, and death. Third, the combustion of sodium azide produces a large amount of unwanted solid products, including a large percentage of sodium oxide, which is a highly caustic and corrosive material capable of damaging lung tissue if inhaled in any significant quantity.[3] Fourth, sodium azide is highly combustible when exposed to high temperatures, and as such, the use of sodium azide in the inflator manufacturing process frequently proved dangerous.

B. *Takata's use of "3110" propellant*

Takata was a pioneer in the industry's movement away from sodium-azide propellants. In 1994, all of Takata's propellants used sodium azide. In 1998, less than 10 percent of Takata's inflator products used sodium azide propellants, and by 2002, Takata had entirely phased out sodium azide-based propellants in its products. The company's move away from sodium azide began with the "3110" propellant, which Takata started producing in 1994.

In the mid-1990s, the 3110 propellant—initially branded by Takata as "Envirosure" or "Envirosure I"—marked a clear advancement in the propellant industry. With strontium nitrate as its oxidizer and tetrazole as its fuel, 3110 presented fewer toxicity and manufacturing-related handling and exposure problems and offered better gas efficiency than sodium azide. The 3110 propellant is also capable of easily propagating a flame at ambient pressures. These are some of the reasons why Takata uses 3110 as both a booster in some of its PSAN inflators and as a main propellant in some non-PSAN inflators.

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[1] Gas efficiency measures the proportion of the propellant that is converted from solid to gas during combustion. Inflator designs attempt to filter the leftover solid waste and other by-products ("effluents").

[2] *Facts about sodium azide*, Centers for Disease Control and Prevention, http://www.bt.cdc.gov/agent/sodiumazide/basics/facts.asp (last visited Jan 15, 2015).

[3] U.S. Patent No. 6,589,375 at 2.

Along with these advances, the 3110 propellant also has drawbacks. It is highly combustible, and if not handled carefully can cause fires and accidents in manufacturing facilities. And the combustion of 3110 produces potentially dangerous gases, including carbon monoxide, nitric oxide, and nitrogen dioxide. While more gas efficient than sodium azide, 3110 is not as gas efficient as other propellants, including those using guanidine nitrate.

C. *The advantages and characteristics of the PSAN-based "2004" propellant developed by Takata*

At the end of the 1990s, Takata began development of a new "smokeless" airbag that would use an even more gas efficient propellant that would produce less particulate matter and less toxic emissions. The result of this work was the "2004" phase-stabilized ammonium nitrate-based ("PSAN") propellant, which first went into production inflators in June 2000 and quickly displaced 3110 as the primary propellant in Takata's inflator products.

The 2004 propellant represented a substantial improvement over Takata's previous propellants in a variety of respects. The compound's gas efficiency is 92 percent—a 130-percent increase over Takata's sodium azide-based propellants. Because of 2004's higher gas efficiency, Takata could make smaller, lighter inflators that used less propellant. In addition, the 2004 propellant's primary ingredient is ammonium nitrate, which is considerably less toxic than the previous industry standard, sodium azide. Indeed, ammonium nitrate is used widely as a fertilizer, and Takata identified the chemical as environmentally benign. Finally, the 2004 propellant emitted fewer gaseous effluents, such as carbon monoxide, nitric oxide, and nitrogen dioxide.

The 2004 propellant consists of ammonium nitrate; potassium nitrate ("KNO_3"); strontium nitrate ("SN"); 5, 5bi-1 H-tetrazole di-ammonium salt ("BHT"); and sodium bentonite ("clay"). The oxidizer is PSAN, and BHT serves as the primary fuel.

Raw Chemical	Inspection Test	Raw Chemical	Inspection Test
Ammonium Nitrate (AN)	• Mass Spectrometer	Potassium Nitrate (KN)	• Mass Spectrometer
	• Concentration		• Assay
	• Sulfate, Nitrite, Chlorides		• Sulfate, Nitrite, Chlorides
	• Assay		• Moisture
	• Water Insoluble		• Water Insoluble
	• pH		• pH
Strontium Nitrate (SN)	• Mass Spectrometer	BHT	• Mass Spectrometer
	• Particle Size		• Assay
	• Chlorides		• Moisture
	• Assay		• Water Insoluble
	• Water Insoluble		• Particle Size
	• pH		
	• Moisture		
Clay	• Moisture		
	• Particle Size		

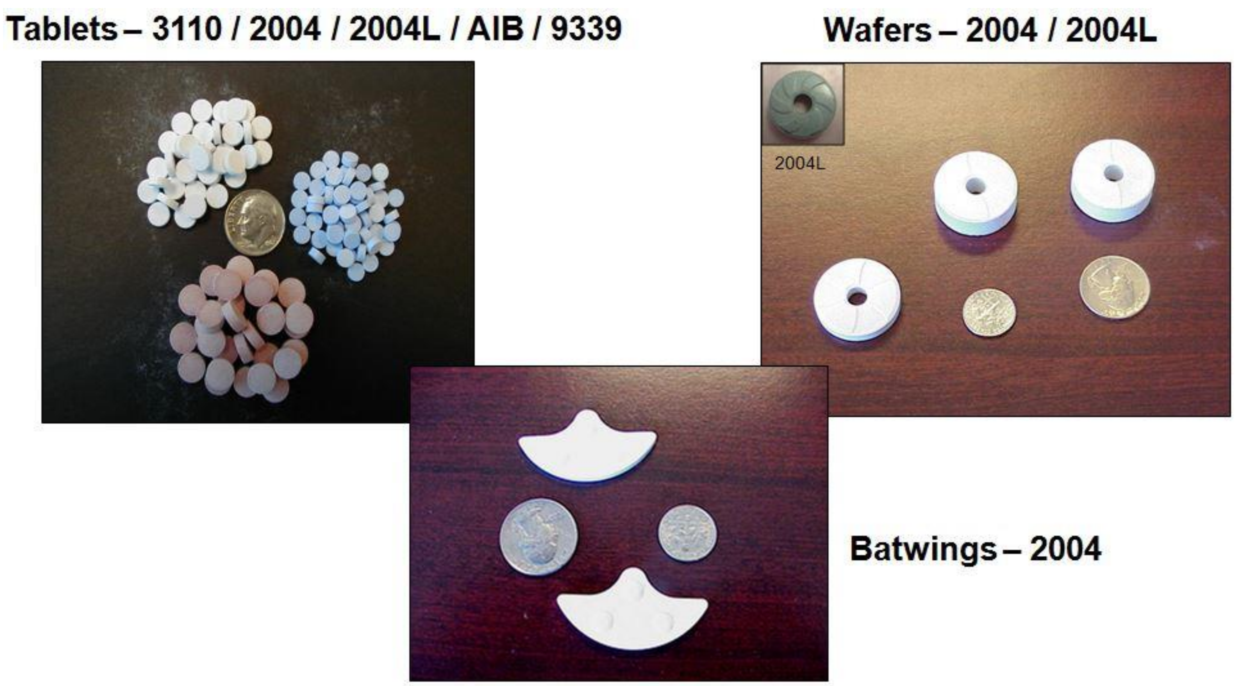
Production of the 2004 propellant occurs at Takata's facility in Moses Lake, Washington, and generally involves a number of steps. Takata receives raw materials from suppliers and subjects them to quality assurance tests, typically including the types of tests illustrated in the table below. To the extent Takata determines that the materials do not conform to specifications, they are returned to the supplier. Among other things, Takata tests the KNO_3, SN, BHT, and clay to ensure they do not contain excess moisture. Takata also tests all the raw chemicals, except for clay, to determine water insoluble levels.

Then the AN, KNO_3, and SN are combined and heated together to form a liquid "pre-batch." The pre-batch is further tested to ensure that it conforms to requisite control points. Pre-batch mixtures that meet all requisite control points are transferred to mixers.

Next, the BHT and clay are combined to form a solid "kit." The kit mixture is also subjected to additional testing to ensure that it meets all requisite control points. A kit mixture that fails to meet any of the requisite control points is rejected.

The pre-batch and kit are then mixed and dried in a controlled environment for a specific amount of time to form a powder called the "raw mix." Any raw mix not mixed in accordance with the requisite controls is rejected. Takata also subjects samples of the raw mix to chemical analysis and Differential Scanning Calorimetry to ensure that AN phase stabilization (discussed *infra*) is achieved. Raw mix that meets all of the requisite control points is left to cool in a storage magazine for at least eight hours and then run through an in-line comil (*i.e.,* a conical mill) to reduce its particle size.

The raw mix powder is then pressed into tablets or wafers. Takata has manufactured the 2004 propellant into batwing-stamped wafers, 10.8-gram wafers, 8.1-gram wafers, 5-gram wafers, 3/16-inch-by-0.060-inch tablets, 3/16-inch-by-0.090-inch tablets, 1/4-inch-by-0.125-inch tablets, and 5/16-inch-by-0.105-inch tablets.



After pressing, the wafers and tablets are subjected to a number of final inspections before packaging.[4] These tests include density and moisture checks. The density specification for the 2004 propellant is 1.68 g/cc to 1.72 g/cc. Takata uses a Karl Fischer Titration to check the post-pressing moisture of the 2004 propellants, which must be no greater than 0.12 percent of the total weight (expressed as "wt. percent").

Takata has used three types of presses to manufacture the final 2004 propellant. Until October 2001, Takata used the Stokes 340 press, a vintage press from the 1960s with manual controls. Because the press had all manual controls, engineers frequently had to check compression and density measurements. Takata took the Stokes press out of production in October 2001. Takata has also used the 40T Gladiator (designated as Gladiator 1, 2, or 3), which is capable of producing a pre-compression force of 10 tons, a maximum final compression of 40 tons, and a maximum output of 300 wafers per minute. The pre-compression force is applied to the propellant to shape the wafer or tablet, and to remove the air from the granules. The final compression force presses the final propellant.

Unlike the Stokes 340, the Gladiator press operation is fully automated and requires fewer manual control—factors that improved efficiency and quality. One function in the automated process was an "auto reject" function, which monitored the amount of force applied to the wafers. If the machine applied an inadequate amount of force, the press automatically rejected the wafer. However, between September 2001, when Takata first introduced the feature, and September 2002, the auto-reject function could be manually turned off by an engineer at the Moses Lake facility. Finally, Takata also uses the Stokes 747 to press tablets. It is capable of a maximum pre-compression force of 1 ton, a final compression force of 10 tons, and a maximum output of 6,000 tablets per minute.

Press	Dates in use	2004 propellants manufactured
Stokes 340	April 2000 to October 2001	Batwings; 10.8g wafers; 5g wafers
Gladiator 1	May 2000 to present	Batwings; 10.8g wafers; 8.1g wafers; 5g wafers
Gladiator 2	September 2000 to present	Batwings; 10.8g wafers; 5g wafers
Gladiator 3	September 2001 to present	Batwings; 10.8g wafers; 8.1g wafers; 5g wafers
Stokes 747	17 presses started between May 2000 and October 2013 are all presently in use	3/16-inch-by-0.060-inch tablets; 3/16-inch-by-0.090-inch tablets; 1/4-inch-by-0.125-inch tablets; 5/16-inch-by-0.105-inch tablets

D. *Takata achieved consistent phase stabilization of its 2004 PSAN propellant*

Solid ammonium nitrate in its pure form exhibits five crystalline phases. The stages are referred to as AN I through V. Broadly speaking, the lower the temperature, the higher the AN phase. AN phase V exists at temperatures below -18°C; AN phase IV between -18° and 32°C; AN phase III between 32° and 84°C; AN phase II between 84° and 125°C; and AN phase I at temperatures over 125°C.

When the phase of AN changes, so too does its volume, density, and shape.[5] Takata recognized that with frequent volume changes, pressed propellant made of a non-phase-stabilized AN could develop micro-cracks, which upon ignition could lead to fractures, increased surface area, and increased burn rates. The phase changes of AN depend

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[4] When Takata began producing the 2004 propellant, it packaged it with desiccant and humidity cards in velostat bags. By 2010, the company packaged the final propellant in mylar bags with desiccant and humidity cards.

[5] Carl Boyars et. al, Minol IV, a new explosive composition containing ammonium nitrate potassium nitrate solid solution: part I, NAVAL ORDINANCE LABORATORY, NOTLR 73-49, 4 (1973).

on a variety of assumptions, including ambient pressure and moisture content. For example, the AN IV > AN III transition temperature, normally around 32°C, occurs at higher temperatures when the AN's water content decreases.[6]

Importantly, additives can stabilize the ammonium nitrate molecule so that the phase changes do not occur under normal conditions.[7] Phase-stabilized ammonium nitrate ("PSAN") is the combination of ammonium nitrate and some additive that extends one of the five AN crystalline stages. PSAN will exhibit transition, but depending on the additive, the transition will not occur under ambient conditions. Because an effective airbag requires precise burning of the propellant, Takata engineers sought to stabilize the ammonium nitrate before using it as an oxidizer.

Takata uses potassium nitrate ("KNO_3") to stabilize the ammonium nitrate in its 2004 propellants. Potassium nitrate extends the stability of AN III—that is, potassium nitrate allows AN III to resist the transition into AN IV at temperatures higher than 84°C and the transition into AN II at temperatures lower than 32°C.

Takata selected potassium nitrate as a stabilizer for a number of reasons. First, Takata saw potassium nitrate as a well-known method of stabilizing AN, and, in particular, a method used by the military to stabilize AN. Second, Takata identified potassium nitrate as a cost-effective and easily manufactured means to achieve phase stabilization. Third, potassium nitrate did not negatively impact ammonium nitrate's performance as an oxidizer in the propellant.

The engineers responsible for Takata's propellant development understood the design challenges that AN presented: (1) the need to use an additive to achieve consistent phase stabilization, (2) the need to pair the AN oxidizer with a fuel that would not negatively affect the thermal stability (*i.e.*, the phase stabilization) of the AN, and (3) the fact that exposure to moisture could affect the combustion characteristics of an AN-based compound. As is typical during the development process, there was internal discussion among engineers at Takata about the potential benefits and drawbacks of using an AN-based propellant. The propellant design engineers concluded that the science of phase stabilization was well established and that any concerns could be addressed to achieve safe, consistent performance of a PSAN propellant.

As discussed in more detail below, the analysis of independent experts from the Fraunhofer Institute for Chemical Technology later confirmed that Takata's 2004 PSAN propellant maintained its phase stabilization over time. These experts concluded that the field ruptures of the relevant non-desiccated PSAN inflators were not caused by a failure of the 2004 propellant to maintain its designed phase stabilization.

IV. Takata's Development and Initial Production of PSAN-Based Propellants

Takata generally subjects its propellants to design verification ("DV") and process validation ("PV") testing.

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[6] See Hong Bo Wu and Chak K. Chan, Effects of potassium nitrate on the solid phase transitions of ammonium nitrate particles, ATMOSPHERIC ENVIRONMENT 42 (2008).

[7] *See e.g.,* A. Deimling, et. al, *Phase transitions of ammonium nitrate doped with alkali nitrates studied with fast X-ray diffraction*, J. of Thermal Anal. 38 (1992) (studying alkali ions, including potassium nitrate, as phase-stabilizers for ammonium nitrate).

A. *Takata exceeded industry development standards to ensure that the 2004 propellant was physically and chemically stable*

Takata began development and initial validation of the 2004 propellant in January 1998, and completed the DV testing by June 1, 1998. Takata conducted heat aging at 107°C for up to 816 hours, more than twice the 400 hours generally prescribed by vehicle manufacturer specifications.[8] Takata conducted thermal cycling testing of the 2004 propellant between -40°C and 105°C for up to 305 cycles, well above the usual requirement of 200 cycles. The 2004 propellant exhibited no significant changes in physical or chemical properties and no significant changes in combustion performance. Takata concluded that the propellant is very robust and that the testing provided very strong evidence that it can be used in any inflator configuration with success.

B. *Before manufacturing PSDI inflators, Takata continued testing the 2004 propellant and set a moisture specification of 0.20 wt. percent to ensure the propellant would perform properly in various environmental conditions*

Based on its research, in May 2000, Takata set the 2004 propellant moisture limit at 0.20 wt. percent. To remain under the maximum 0.20 wt. percent moisture limit, the report recommended that no more than 0.10 percent moisture be gained during handling of the propellant. In order to determine how quickly the propellant gained moisture, Takata tested the amount of moisture gained over time at varying levels of relative humidity. The result was the following recommended maximum exposure times during handling:

Relative Humidity (RH)	Recommended Maximum Exposure Time
<30 percent	24 hours
30-40 percent	3 hours
40-50 percent	2 hours
50-60 percent	1 hour
>60 percent	15 minutes

Subsequent testing completed in August 2003 determined that if the moisture content of the propellant is low enough after processing, a gain in moisture of about 0.05 wt. percent is acceptable during handling and storage. Using this more stringent threshold for allowable moisture gain (0.05 wt. percent rather than 0.10 wt. percent), the report found the following limits on exposure times during handling and storage:

Figure 1: Allowable Exposure Times for 2004 Propellant

Relative Humidity	Exposure Time for >0.05% Moisture Gain		
	Batwings	Thins	Tablets
<20%	>24 hours	>24 hours	>24 hours
30%	4-6 hours	>24 hours	>24 hours
40%	3-4 hours	>24 hours	>24 hours
50%	<0-0.4 hour	4-6 hours	2-3 hours
60%	Immediate	Immediate	Immediate

[8] Vehicle manufacturer specifications are at the inflator level. Accordingly, Takata tests its propellants to standards that replicate (and exceed) the vehicle manufacturer specifications for inflators.

Later, in 2007, Takata changed the maximum moisture level for the 2004 batwings from 0.20 wt. percent to 0.12 wt. percent. And in 2014, Takata again changed the maximum moisture level for the 2004 propellant from 0.12 wt. percent to 0.07 wt. percent due to a request from a vehicle manufacturer. Since the start of production, Takata added desiccant pouches to all shipments of 2004 propellants, as well as the pre-pressed granules.

C. *2004L propellant testing: Takata encountered issues during moisture testing, leading to changes in the 2004L moisture specification and the addition of desiccant*

Takata developed a reformulated PSAN propellant known as "2004L" for use in Takata's later-generation X-series inflators, and the company conducted DV testing of the 2004L propellant in December 2005. Takata evaluated the 2004L propellant against the USCAR-24 specifications for airbag inflator validation (specifications prescribed by multiple U.S. vehicle manufacturers beginning in June 2004), as well as against the inflator specifications prescribed by a certain Japanese vehicle manufacturer that were widely considered the industry's most stringent. Takata conducted the tests in both SDI (single-stage driver) and SPI (single-stage passenger) inflators. The testing included high temperature testing, accelerated heat aging, vibration resistance, thermal-shock testing, low and high-G testing, and sequential-environmental testing. These tests did not include high humidity combined with thermal-cycling.

In June 2007, Takata tested the effects of exposing the 2004L propellant to high levels of relative humidity ("RH") followed by drying the propellant. Takata found the 2004L formulation was able to withstand exposure to 60 percent RH for 24 hours, followed by drying, with no change in ballistic performance. That result represented an improvement over the 2004 propellant, which could experience up to 50 percent RH for 24 hours before changes in ballistic performance began to occur. An additional improvement was that 2004L operated at lower pressures than 2004 due to a reduced slope of the burn rate.

In September 2007, Takata began PV testing the 2004L propellant. PV testing included: baseline testing, heat aging, thermal shock, heat aging combined with thermal shock, and a mechanical sequential test, which encompassed a combination of dynamic high-G testing, vibration-temperature cycle testing, and drop testing.

Takata observed certain failures in the PV testing of the 2004L propellant that were evidently due to manufacturing issues. Takata also observed elevated ballistic results following environmental aging, which Takata attributed to the possible effects of moisture. In February 2008, Takata studied the effects on the 2004L performance of placing moisture-absorbing desiccant in the test inflators. The study tended to confirm that moisture was a factor in the test failures and that the use of desiccant was helpful in alleviating the issues. A report on the study surmised that moisture from within the main propellant condenses on the propellant surface during thermal shock conditioning and degrades the propellant. After further test failures, some engineers at Takata believed that the problem was the moisture level of the manufactured 2004L propellant.

In March 2008, Takata engaged an expert from a technical university in Japan to analyze the test failures. The expert suggested that it was possible that thermal cycling was causing moisture to accumulate on the surface of the PSAN in the 2004L propellant, and this accumulated moisture might cause a re-crystallization of the PSAN, which in turn could cause more aggressive combustion.

After completing additional moisture testing on the 2004L propellant in April 2008, Takata decided to lower the moisture specification level for the 2004L propellant from 0.10 wt. percent to 0.06 wt. percent. The testing indicated that 2004L wafers with 0.10 wt. percent moisture content exhibited an elevated ballistic output after heat aging and thermal cycling, and that this elevated ballistic output could reduce the inflator's safety factor (typically expressed as a ratio of the pressure required to burst the inflator vessel and the container pressure generated within the inflator upon deployment). With the lower moisture specification and the addition of desiccant, X-series inflators containing the 2004L propellant subsequently passed PV testing.

Takata initially attributed the moisture issues encountered in 2004L testing to moisture introduced into the propellant as a result of the manufacturing process, not environmental moisture from external sources. Takata hypothesized that during thermal shock testing, moisture inside the 2004L propellant was constantly released and reabsorbed on the surface of the propellant, which caused degradation of the propellant.

Following initial reports of field ruptures involving non-desiccated 2004 PSAN inflators, Takata began considering the effect of external moisture intrusion on 2004L propellant. In late 2009, a vehicle manufacturer asked Takata to consider the Helium leak rate of the X-series inflators and the moisture absorption potential of the 2004L propellant to assess the inflator's ability to survive increased moisture exposure. In response, Takata calculated the amount of moisture that would migrate into the inflator with a given leak rate and concluded that the potential moisture intrusion into an inflator during the life cycle of the inflator will never exceed the maximum allowable moisture content. Takata believed that the addition of desiccant in the X-series inflators provided an extra margin of safety for moisture ingress.

D. *Fraunhofer's testing of returned inflators and aged propellant found no indication of chemical degradation or loss of AN phase stabilization*

In late 2009, Takata retained the Fraunhofer Institute for Chemical Technology ("Fraunhofer") to test the chemical stability, phase stabilization, and performance of the 2004 PSAN propellant removed from recalled PSDI inflators (originally manufactured beginning in 2000). For comparison purposes, Fraunhofer also tested newly produced 2004 propellant.

In a March 2010 report, Fraunhofer shared its initial findings on the chemical stability, phase stabilization, and performance of the 2004 propellant. Fraunhofer's analysis found no significant chemical changes between the recalled propellant and the newly produced propellant.

Fraunhofer's three main findings were as follows:

- The analysis of internal gases in the inflators[9] showed no anomalies and raised no problems with chemical stability. The nitrous oxide level, which could only increase with decomposition of AN, did not raise any concerns.
- Fraunhofer's testing[10] showed phase stabilization of the 2004 propellant to at least 100ºC with no deterioration.
- Fraunhofer also looked for changes in the thermal properties or energetic performance of the propellant, since either factor could indicate decomposition or changes in the chemical state. Fraunhofer reported

[9] To test the internal gases, samples were taken from the recalled and newly produced inflators and injected into a gas chromatograph. The components were separated, calibrated, and their percentage of concentration in the samples was determined.

[10] Fraunhofer tested phase stabilization by (i) X-ray diffraction ("XRD") tests at room and elevated temperatures, and (ii) differential scanning calorimetry ("DSC"). The DSC test heated the propellant up to 350ºC and then recorded the reactions over the course of the increased temperature. Endothermic reactions (*i.e.*, when the heat is being absorbed) indicate crystal phase transitions in the ammonium nitrate.

there was no change in thermal properties or energetic performance of recalled propellant as compared to the new propellant.

On September 20, 2010, Fraunhofer issued a final report on these issues, summarizing its test results on phase stability, physical properties, and performance of the 2004 propellant. Fraunhofer confirmed its initial findings, most importantly:

- "The analysis of the internal gas composition of the recalled inflators reveals only very small concentrations of decomposition products and no critical changes as compared to new inflators."
- "The X-ray diffraction tests show continued stabilization of the ammonium nitrate in the recalled propellant through phase III in the temperature range 35ºC to 100ºC."

Finally, Fraunhofer's February 2015 summary report concluded that the "results of these initial investigations showed no indication for chemical degradation and no loss of phase stabilization of ammonium nitrate in the 2004 propellant." Based on its findings, Fraunhofer opined that the possibility of chemical degradation could be set aside for further root cause analysis.

V. Takata's Development and Initial Production of the Original PSAN Inflators

A. *Background on Takata's development of PSAN inflators*

1. *Validation testing is done according to specifications prescribed by the vehicle manufacturer*

The government does not specify the requirements for manufacturing or testing airbag inflators. Equipment suppliers like Takata build and test airbag inflators according to specifications prescribed by their customers, the vehicle manufacturers. Some vehicle manufacturers prescribe their own unique specifications, and some use multi-manufacturer specifications, such as the USCAR specifications used by the U.S. automakers. Because the specifications are prescribed by the vehicle manufacturers, they are subject to exceptions and variances approved by the customer.

New inflator products undergo a four-step design review ("DR") process. During the first two steps, DR1 and DR2, Takata performs internal concept validation ("CV") testing on the inflators. CVs are performed on prototype inflators that are built on a one-off basis by Takata's research and development team. The CV tests vary depending on the demands of the intended vehicle manufacturers, but the tests usually include ballistic testing and helium leak testing to ensure structural integrity and strength. Multiple rounds of CV testing may be performed. If a concept passes CV testing and is approved by Takata's management, it moves on to the validation process.[11]

The validation process consists of DR3 and DRPV, the last two phases of the DR process. DR3 consists of design verification ("DV") testing, which demonstrates that the design is capable of meeting the customer's performance specifications. DRPV consists of process validation ("PV") testing, which demonstrates that the product can be mass-produced to meet the customer's performance specifications. At the DV stage, Takata produces a Design

[11] At this early stage, U.S. vehicle manufacturers also require that the inflator design be "Qualified for Sourcing" ("QFS") before Takata presents the design to the vehicle manufacturer as a potential product for purchase. The QFS process is also called "book shelving."

Failure Mode Effects Analysis ("DFMEA"), which identifies potential points of failure in the design and assesses their risk. Takata then tests pre-production inflators to the manufacturer's specifications and produces a DV test report. If the DV testing is deemed acceptable, the PV process begins. The PV process includes the creation of a Process Failure Mode Effects Analysis ("PFMEA"), which identifies potential failure points in the manufacturing process. Takata then typically tests inflators produced on fully operational production lines and generates a PV test report. If the PV testing is deemed acceptable, the product is ready for production. Because PV testing generally occurs after DV testing and is intended to validate the production-line products and equipment, PV testing in certain circumstances can effectively serve to demonstrate that issues identified in DV testing have been resolved.

When a significant change is made in the design or manufacturing process for an inflator, either to address a problem identified in testing or to improve the performance or production of the inflator, Takata may perform "delta" DV or PV testing of the inflator (also sometimes referred to as DDV or DPV tests). Sometimes an inflator may fail to meet the requirements of DV or PV testing because of an error or problem with the test itself, and in such instances, the test may be re-run. In cases where the inflator fails a properly conducted test and the specification cannot be satisfied, Takata may ask the vehicle manufacturer to approve a "deviation" from the requirements of the specification.

Inflators are also subjected to a second round of DR testing when assembled into an airbag module. The airbag module DR process includes the module DV and PV tests, which are designed to test the performance of the modules as a whole under various conditions.

Lot acceptance tests, or "LATs", are performed on a sampling of each production lot of inflators as they roll off the assembly line.[12] The LATs often involve some combination of tests similar to those performed in DV and PV testing. If a sample inflator fails a test, the lot is generally scrapped unless some appropriate exception applies.[13] If there is a failure during the LAT process, a Non-Conforming Material Report ("NCMR") is created. A member of Takata's Quality Control staff will then confer with Takata's engineering and quality control teams to decide what should be done. Members of both the engineering and quality control teams have to give approval before the affected items may be shipped.

In addition to testing the inflators and modules in the laboratory, there is also testing of the assembled airbag module in the vehicle. Takata ships sample modules to vehicle manufacturers, which install the modules into their vehicles. The vehicles—which contain crash dummies and various sensors—are crashed at various speeds to determine the performance of the airbag. Specifically, the tests analyze the forces experienced by the crash dummies at various places—such as the head, neck, and chest. These tests are also required to demonstrate compliance with the Federal Motor Vehicle Safety Standards ("FMVSS"), which specify the maximum forces that may be experienced by the crash dummies in several different types of crashes.

2. *Takata's inflators are subjected to an extensive battery of tests*

Takata subjects its inflators to a number of tests at its North American facilities before the inflators are deemed ready for shipment to Takata's customers. Those tests include:

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[12] In recent years, ballistic tests have also been performed on propellant lots prior to inflator manufacturing.

[13] Although LATs are performed at the end of the manufacturing process, they also can be performed at any stage of the design process. For instance, if a vehicle manufacturer wants a sample lot of inflator prototypes for its own in-house testing, LAT tests would be performed on the lot to inform the vehicle manufacturer of the expected performance of the lot it will receive.

Ballistic testing. In ballistic testing, the test inflator is deployed in a sealed tank that measures the pressure created over a set period of time (a "pressure-time curve") by the gas released from the inflator inside the tank. This ballistic test indicates the inflator's ability to fill up the airbag at the proper rate upon deployment. To ensure proper inflator performance in a variety of environmental conditions, ballistic testing is generally performed at hot, cold, and ambient temperatures based on each vehicle manufacturer's specifications.

Conditioning tests. For some stages of product development, ballistic testing also includes environmental simulation, in which the inflator is deployed after being subjected to various changing conditions. Although customer specifications vary, conditioning tests generally include the following or some combination of the following:

- **heat-age testing**, in which the inflators essentially are baked in an oven for a set amount of time to simulate aging, and then deployed at cold, ambient, and hot temperatures;
- **humidity testing**, in which inflators are deployed after exposure to constant or varying levels of moisture and temperature;
- **thermal-shock and thermal-cycling testing**, in which inflators are deployed after fast or slow changes in temperature;
- **dynamic shock testing**, in which inflators are deployed after being shaken several times with an increased "G" load; and
- **drop testing**, in which inflators are deployed after being dropped onto a steel plate.

Helium leak testing. In addition to ballistic testing of inflators, Takata's procedures provide that every inflator that Takata ships for sale to a customer (as well as those that are used internally for testing) undergoes helium leak testing. The helium leak test, which is standard in the inflator manufacturing industry, is designed to assure that the inflator is sealed properly and will resist the entry of moisture. Under Takata's procedures, if an inflator fails the helium test, it is discarded and not sent to a customer. In a helium leak test, a vacuum pump is used to remove as much air as possible from an inflator and the inflator is backfilled with helium and sealed. The inflator is then placed in a sealed chamber in which a vacuum is created around the outside of the inflator. This process creates a pressure differential between the inside of the inflator and the chamber surrounding the inflator. The rate at which helium leaks from each inflator is then measured and if that rate is too high, the inflator is discarded.

Hydroburst testing: In the hydroburst test, an inflator is filled with water by means of an accumulator that pushes water into the inflator to increase its internal pressure. The pressure is increased until the inflator vessel bursts, at which point the amount of pressure the inflator can handle is recorded as well as the location of the burst (to check the various welds). Essentially, the purpose of this test is to measure the strength of the inflator vessel.

Electrostatic discharge test: This test is used to ensure that inflators will not improperly ignite and deploy when subjected to a certain amount of static electricity.

Depending on the vehicle manufacturer's requirements, inflators also may undergo:

- **effluent testing**, which measures the types and amounts of gases released by a deployed inflator;
- **a tank wash,** which measures the amount of solid particulates that exit the inflator during deployment; and

- **a flaming test** (required by U.S. vehicle manufacturers), in which an inflator is deployed and observed using high speed video to determine whether and how far flames jet from the inflator's gas orifices, as well as the duration of the flame.

Auto-ignition tests: Tests also are performed to assess inflator performance in the event of a fire. Takata's inflators are designed with an auto-ignition function to ensure that the inflator will automatically deploy in the event of a fire, either in a car that has been in accident or while being transported. Without inflator auto-ignition, the heat from a fire (for example, during transport) could raise an inflator's internal pressure causing it to deploy with more force than intended or potentially explode. The auto-ignition tests, which are standard in the inflator manufacturing industry, are designed to ensure that Takata's inflators self-deploy normally and safely when subjected to the heat of a fire. To test the inflators' auto-ignition function, Takata performs:

- **hot plate testing**, in which inflators are placed on a hot plate and the rate of heating is controlled;
- **slow heat testing**;
- **high temperature oven testing**;
- **BAM**[14] **burner testing**, in which the inflator is heated on a burner or gas grill; and
- **bonfire testing**, in which a pallet of inflators is burned in a bonfire. The bonfire test is required by the U.S. Department of Transportation as a condition for allowing the safe transport of inflators.

Safety factor calculations also are performed for each inflator model. Various vehicle manufacturers calculate the safety factor differently. As a general matter, this calculation is a ratio of the strength of the inflator structure to the maximum internal deployment pressure inside the inflator. The safety factor is calculated from data generated through hydroburst testing and ballistic pressure measurements.

In addition to all the testing described above for the inflators themselves, the airbag modules into which inflators are installed also are subjected to extensive CV, DV, PV and LAT testing prior to finalization of a design and mass production and shipment of the products to the customer.

B. *DV testing of the original PSDI driver inflator and a switch in the design of the propellant wafer prior to PV testing*

After development of the 2004 propellant, Takata's inflator design group, Automotive Systems Laboratory ("ASL"),[15] began developing propellant wafer designs to use in the initial PSDI inflator, Takata's first PSAN driver inflator. These designs included shark fin-shaped wafers and batwing-shaped wafers.

In the summer of 1999, ASL chose to use the shark fin design (pictured) because of concerns about the potential for variations in the density of the batwing wafers.

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[14] Bundesanstalt für Materialforschung und –prüfung, a German safety certification authority.

[15] Takata established ASL in 1991 in Armada, Michigan, as a research and development center. *See* http://www.takata.com/en/about/history.html.

Shark fin wafers (white) of the kind used in PSDI DV

Takata completed DV testing for the PSDI inflator using shark fin wafers in October 1999. Takata completed a second, delta DV test using the shark fin design by January 5, 2000.

Information indicates that in October 1999, during module DV testing conducted at the vehicle manufacturer's facilities, a rupture occurred of the PSDI inflator. Takata and the vehicle manufacturer reviewed the issue, and Takata advised that the cause of the rupture was believed to be improper welding, which Takata committed to address.

Information also indicates that a second PSDI inflator experienced some breakage and leakage during another module test in January 2000 at the vehicle manufacturer's facilities. After reviewing the issue, Takata advised it believed the issue stemmed from the vehicle manufacturer's assembly of the module, and Takata took steps to address the issue.

In January 2000, Takata and its customer performed sled tests using modules containing PSDI inflators with both shark fin and batwing wafers. The module with the shark fin wafers failed to satisfy one of the test criteria. Takata believed this issue could be remedied, and continued to advocate for the use of the shark fin design due to concerns about the potential for wafer density variations in the manufacturing of the batwing wafers and thus the potential for variability in ballistic performance. However, in February 2000, the customer instructed Takata to use the batwing wafer design.

This switch in the wafer design came late in the design cycle for the PSDI. Production was slated to start in June 2000, just four months later, which did not leave sufficient time for the normal DV and PV testing process. DV and PV testing typically requires more than three months to complete, and new equipment was required to set up the production line for the batwing-containing inflators at Takata's inflator assembly facility in LaGrange, Georgia.

For that reason, rather than using units assembled on a finished production line, Takata performed the initial PV testing for the PSDI using pre-production batwing inflators. This PV testing of these inflators occurred from February 2000 until late May 2000. The batwing wafers used in the PV testing were produced in Takata's Armada, Michigan research and development facility using a non-production press.

In addition, because the batwing design was more difficult to press and required more time to press, the switch in wafer designs meant that Takata did not have enough Gladiator presses at its Moses Lake, Washington propellant production facility to meet production volumes. Accordingly, the Stokes 340 press, which had been purchased for use in the Armada facility and was not intended for mass production, was shipped to Moses Lake to help increase pressing capacity. As discussed above in section III.C, the Stokes 340 press had certain limitations relative to the Gladiator press. Specifically, the Stokes 340 lacked press-force monitoring capabilities, which limited the ability to assure adequate density of the wafers.

C. *Summer 1999: In an effort to improve the manufacture of the propellant wafers, Takata began to consider milling BHT*

At roughly the same time as the switch to the batwing wafer—after DV testing but before PV testing—Takata also changed the way it processed its 2004 propellant. In the summer of 1999, in anticipation of starting mass production, Takata analyzed methods to improve manufacture of the propellant. One issue Takata found was that when BHT (the fuel) is hand-blended with clay, the final propellant product did not flow well in the propellant press. Takata found that milling the BHT would change the particle size such that the propellant flowed better in the press. This change was advantageous for mass-production purposes: Better flowing propellant means more consistently pressed wafers and less down time due to clogged presses. Takata began the milling of BHT in early January 2000.

D. *April to June 2000: Inaccurate PSDI PV test results are reported to a vehicle manufacturer*

Initial PV data from Takata's baseline testing of the PSDI was available as early as April 2000 and was given to the vehicle manufacturer customer by a TKC engineer during a production process inspection of the LaGrange facility that April. Although there were no ruptures in this initial testing, the data was inaccurately reported as showing compliance when in fact it was not compliant due to variability in certain ballistic test results that were outside the vehicle manufacturer's specifications. During the process inspection, the vehicle manufacturer requested details on the specifications of the PV lots. Pursuant to this request, on April 26, 2000, a representative of the vehicle manufacturer was sent the specification of the PV lot, which specifically noted that the propellant wafers used in the PV testing were quasi-mass production products that were made on a single shot press. (The phrase "single shot press" referred to the research and development press used at Takata's Armada, Michigan facility.)

PV tests continued in the following months. In late May 2000, three of the units ruptured during testing. PV testing concluded by early June.

In June 2000, the LaGrange facility began production of the PSDI inflator and Moses Lake began production of batwing wafers.

A final PV report addressed to the vehicle manufacturer from TKC and dated June 23, 2000 did not reference the ruptures and included other erroneous data that did not match the actual test data.

Two Takata engineers issued reports in the October-November 2000 timeframe—the "Trimble report" and the "Sheridan report" (named for the employees who prepared the reports)—that documented the inaccuracies in the June 23 PV report.

The Sheridan report stated that the test report had incorrect data, data that could not be validated, data that was incorrectly labeled, or data that did not exist. The Trimble report did not mention or comment on the June 23 PV report, but provided an accurate account of the underlying PV test data. The Sheridan report was apparently distributed to certain engineers, though it is not known how widely it was distributed. It is unclear whether the Trimble report was provided to anyone else at Takata at the time. It appears that no action was taken in response to the reports, and there is no indication that either report was provided to the vehicle manufacturer in 2000.

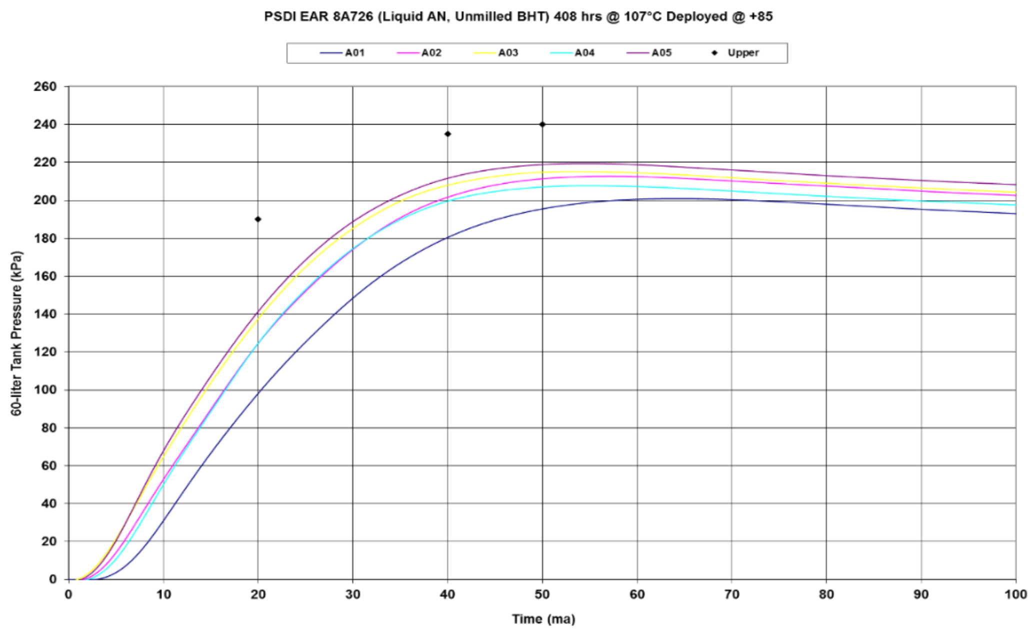
E. *Late 2000 to early 2001: Takata identifies the milling of BHT as a factor in initial PV failures and conducts tests showing that the use of unmilled BHT improved the PSDI's test results*

Among possible explanations, Takata engineers identified the milling of BHT as one potential factor in initial PV testing failures.

From August 2000 to March 2001, Takata engineers performed additional testing on milled and unmilled BHT inflators. Testing on inflators using milled BHT resulted in a repeat of the failures seen in the initial PV testing. In October 2000, a U.S. engineer noted that testing showed milled BHT was weaker than unmilled BHT, that propellant with unmilled BHT passed heat aging and thermal cycling tests, and that maintaining correct pressing density was important. In mid-October 2000, Takata converted its PSDI manufacturing process to use unmilled BHT. In late

October, a successful high-temperature aging test was completed using unmilled BHT inflators. From late October 2000 on, all inflators were produced using unmilled BHT fuel.

In November 2000, Takata conducted a complete re-test (delta PV) of all of the conditioning tests in the vehicle manufacturer's validation testing specifications. This testing was complete by March 2001. The tests showed normal inflator behavior, with no ruptures. A few test data points were slightly above or below customer specifications, but Takata believed at the time and continues to believe that these test variations were not significant and that the inflator performed adequately. This re-testing was not disclosed to the customer.



Passing High Temperature Aging test performed on a PSDI inflator with unmilled BHT October-November 2000.

At the same time that the full battery of delta PV tests were being run, Takata also ran a series of high temperature aging tests on unmilled and milled BHT combinations (along with tests of different processing methods for ammonium nitrate).[16] On March 19, 2001, a report was issued. High temperature aging testing revealed that one of the milled BHT configurations failed, resulting in a rupture, but that all configurations with unmilled BHT passed. Accordingly, the report recommended that Takata not use milled BHT. (As noted above, Takata had already stopped using milled BHT months earlier, in late October 2000.)

Further testing of the PSDI inflator confirmed that the unmilled BHT formulation resulted in normal performance. In October 2004, Takata validated the PSDI inflator for production in its Monclova, Mexico plant. This validation included baseline ballistic testing. Again, this testing showed normal performance. In 2007, after the first PSDI field

[16] The different processing methods for ammonium nitrate were "prilled" (dry) and liquid ammonium nitrate. The only difference is how Takata received the AN. Prilled ammonium nitrate requires that Takata dissolve the AN into a liquid; by receiving the AN in liquid form, Takata eliminated that processing step. All PSDI developmental work and the original PV were done with prilled ammonium nitrate. In September 2000, Takata switched to liquid ammonium nitrate. Both configurations passed when used with unmilled BHT, and there is no indication that the switch had a significant effect on inflator performance.

ruptures, Takata again tested the PSDI, but this time the inflators were intentionally configured to produce high output, in order to see if they would rupture. Although test results for some units were slightly above specification after conditioning, no inflators ruptured and the results were within expectations given the use of intentionally high output inflators.

Because milled BHT inflators produced between June and October 2000 were installed in vehicles, in early 2001 some Takata engineers apparently considered the possibility that these inflators could pose a risk in the field, but there is no indication that any conclusion was reached at that time.

In 2007, when several PSDI inflators ruptured in the field, Takata considered whether the ruptures were caused by milled BHT. When it investigated, however, it found that the first ruptured inflators were built with *unmilled* BHT, and therefore Takata ruled out the milling of the BHT as a potential root cause of the initial field ruptures.

F. *Development of the original PSAN PSPI and SPI passenger inflators in 2000*

In 1999 and 2000, Takata also experienced challenges in the development and testing of the original PSAN passenger inflators, the PSPI and SPI. Takata made a series of design changes in these inflators in response to early problems in DV testing. In DV and PV testing in the spring and summer of 2000, there were multiple ruptures of the SPI and failures of the PSPI to satisfy ballistic specifications, as well as one or more apparent ruptures of a PSPI. As with the PSDI, there is no indication that these testing failures were reported to the vehicle manufacturers before Takata started production of these inflators.

Takata engineers conducted additional testing to understand the reason for these failures, particularly with the SPI inflators. Eventually, as with the PSDI driver inflator, Takata attributed the ruptures and failures that occurred during validation testing of the SPI and PSPI passenger inflators to the use of milled BHT. All three of these inflator types used the same formulation of the original PSAN propellant with milled BHT fuel. Takata ceased the use of milled BHT in the production of all three of these inflators in late October 2000. All of the propellant wafers for the SPI and PSPI made on and after October 12, 2000 used unmilled BHT. Subsequent tests demonstrated that these inflators made with unmilled BHT performed normally.

In 2003, when the assembly lines for these inflators moved from LaGrange, Georgia to Takata's facility in Monclova, Mexico, Takata conducted successful revalidation testing for the new production lines, just as it did for the line producing batwing driver inflators.

G. *Safety implications of the 2000 validation issues and Takata's actions to address testing and reporting deficiencies*

Ultimately, Takata has concluded that the milling of BHT during the initial production period of the first PSAN inflators from June to October 2000, while it appears to have resulted in failures in validation testing, is not the root cause of the ruptures of these inflators in the field.

Takata based this conclusion on several findings. First, it consulted with an expert in statistical analysis at Georgia Institute of Technology, who analyzed the frequency of inflator failure among milled BHT inflators as compared with unmilled BHT inflators for all reported field events involving the driver and passenger inflators that were produced with both milled and unmilled BHT. In a report dated September 26, 2015, the expert found no statistical difference in the frequency of reported field ruptures between the milled and unmilled BHT inflator populations. An engineer from Takata's U.S. inflator production engineering group also conducted an analysis of the effect of milled BHT and concluded that the milling of BHT was not a root cause of the failures in the field. In addition, Takata engaged an expert in aerospace engineering from Georgia Tech who reviewed both the analysis of Takata's engineer and the analysis of the statistical expert and concurred in the findings of both as having a solid scientific basis.

Most importantly, all of the PSDI, SPI, and PSPI inflators that were produced with milled BHT in the first months of production in 2000 have been subject to national recalls for some time.

In subsequent years, Takata has encountered numerous other specific issues in the validation testing of various PSAN inflators, and in a number of instances, there have been lapses in the integrity of the company's validation test reports. Takata is continuing to review the issues relating to data integrity and is committed to disclosing all significant issues to its customers and NHTSA and to cooperating with authorities and vehicle manufacturers to address those issues. Takata is committed to take all necessary steps to improve its testing and safety-review procedures, as detailed further below.

Takata does not believe that these testing and reporting issues relate to the long-term propellant-degradation phenomenon associated with the field ruptures that led to Recall Nos. 15E-040, 15E-041, 15E-042, and 15E-043. Nevertheless, Takata has expressed deep regret for all failures and deficiencies identified in its inflator validation testing. Takata has acknowledged that the handling of the PV testing for the original PSAN inflators in 2000, including the reporting of inaccurate data and the omission of important test results from the reports provided to customers, was totally unacceptable and inconsistent with Takata's role as an equipment supplier. The same is true in every other instance where Takata has identified deficiencies in the integrity of its testing and reporting procedures. Takata also gave notice to NHTSA on December 31, 2015 that Takata and TKC terminated the employment of several individuals in relation to the subject matter of the November 3, 2015 Consent Order. Takata recognizes that it should always share the correct and accurate testing data with the vehicle manufacturers when that data is important to the design and performance of the equipment supplied by Takata.

H. *2002 to 2003: Issues with the early development of PSDI-4 inflators*

In late 2000, in response to customer demands and the expected development of USCAR specifications, Takata began development of the PSDI-4 inflator, which was designed, among other things, to be lower in weight and cost than the PSDI. Takata conducted validation testing of PSDI-4 inflators by reference both to specific customer specifications and proposed USCAR specifications. In August 2002, Takata conducted PSDI-4 PV testing to a vehicle manufacturer's specifications, but the PV report provided to the customer failed to include certain ballistic curves that were out-of-specification. Similarly, a delta DV report prepared for a vehicle manufacturer in December 2002 failed to include certain out-of-specification ballistic curve data.

Further, during delta PV testing to USCAR specifications in January 2003, the PSDI-4 did not meet all USCAR specifications, and the delta PV report noted that certain deviations from USCAR specifications would be required. Subsequent delta PV testing to USCAR specifications in July 2003 had similar results.

In 2002, Takata observed two ruptures during development of the PSDI-4. The first rupture occurred on February 17, 2002 in a PSDI-4 at the vehicle manufacturer's test lab during Out of Position ("OOP") testing, which simulates the airbag's performance when the occupant is not seated properly in the vehicle. Takata determined the rupture was caused by propellant overpacking, which was in turn caused by an operator's failure to perform a height check on the inflator. The second PSDI-4 rupture occurred during module DV testing on April 25, 2002 at Takata's module facility in Cheraw, South Carolina. Takata concluded that the rupture was caused by an operator's inadvertently including two volume reducers in the inflator instead of the required one reducer. Takata implemented countermeasures to address the causes of both ruptures promptly after learning of them, and also took steps to quarantine and contain any inflators potentially affected by the volume reducer issue.

Pursuant to DIR No. 15E-040, all of the Takata PSAN batwing driver inflators from start of production to end of production are under recall in the United States. Those recalls encompass all of the PSDI-4 inflators.

VI. 2003 to 2004: Early PSDI Field Ruptures

A. *May 2003 to June 2003: An "overpack" rupture in Switzerland*

In May 2003, a PSDI-4 inflator ruptured in a vehicle in Switzerland. The inflator was manufactured on December 11, 2001. Takata investigated the incident and found that the only way a similar failure could be duplicated was by overloading the main 2004 propellant in the secondary chamber (referred to as "overpacking"). Takata also concluded that overpacking was the likely cause because: (1) there was a problem with the height-check equipment used on the line where the relevant inflator was made in December 2001 (the equipment would crush an extra batwing rather than identify it); (2) there was a new set of operators working on the second shift the day the inflator was made; and (3) there was a relatively high frequency of load problems occurring on the manufacturing line at that time.

On July 2, 2003, Takata informed the vehicle manufacturer that Takata was confident that "propellant overload" was the likely cause. The corrective plan involved a quality assurance/control change to include a propellant height check/weight detection system (to confirm the proper number of batwing wafers) and also the discontinued use of a certain type of piston on the manufacturing line. Takata implemented both of these changes.

In a November 20, 2009 letter from NHTSA in RQ09-004, which NHTSA opened to assess the adequacy of Recall Nos. 08V-593 and 09V-259, Takata was asked whether it sold any inflators similar to those covered by the two identified recalls to any other customer. In its February 19, 2010 response, Takata noted that approximately 448 PSDI-4 inflators installed in vehicles exported to the United States were manufactured in October 2001 with the same production process as some of the inflators covered by a subsequent recall (No. 10V-041). Takata stated that "there have been no reported incidents involving malfunctions of these inflators," and it is "convinced that the inflators sold to the vehicle manufacturer contain no safety-related defect." A U.S. engineer at Takata later considered whether Takata's response might have been less than complete because it did not mention the Swiss event. The engineer concluded that the response was accurate because the inflator involved in the Swiss event was not among the inflators made during the production period addressed in Takata's response.

B. *May 2005: Takata learns of Event 0 and begins an investigation*

The so-called "Event 0" (so named because it preceded the field ruptures in 2007 that Takata and the vehicle manufacturer came to call Events 1, 2, and 3) occurred on May 2, 2004, when an inflator ruptured in a 2002 vehicle in Alabama. In a 2009 NHTSA submission, the vehicle manufacturer stated that it learned of this incident that same month—in May 2004—and that it alerted Takata of the incident at that time. However, on November 20, 2014, the vehicle manufacturer confirmed in a Senate hearing that it first told Takata about the event in May 2005.

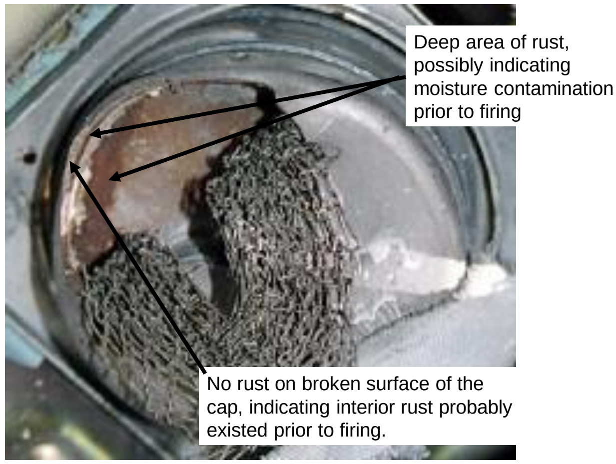
The earliest known communication from the vehicle manufacturer to Takata regarding Event 0 was May 4, 2005, when an employee of the vehicle manufacturer emailed a senior engineer at TKC regarding the event. That email was forwarded to a U.S. employee of Takata and a senior U.S. executive at Takata the following day. The email stated that photos of the event would be in Auburn Hills by Friday, May 6, 2005. On May 6, the U.S. employee alerted a senior U.S. engineer about the issue. Also on May 6, an engineer in TKC's Global Inflator Organization ("GIO") sent four photos (pictured below) of the ruptured inflator obtained from the vehicle manufacturer to the U.S. employee, the senior U.S. executive at Takata, and a senior U.S. engineer in the inflator design group. By May 7, 2005, Takata located the manufacturing data for the Event 0 inflator (manufactured on October 26, 2001) and propellant lot (manufactured on October 13, 2001) and verified that manufacturing data reflected that the Event 0 inflator met all applicable LAT testing specifications.

Pictures of Event 0 Received May 6, 2005

On Monday, June 13, 2005, a U.S. engineer in the inflator production group summarized his opinion of Event 0 based on very limited data. The engineer concluded that:

- the anomaly probably initiated in the secondary chamber in the cap material in the region of the booster tubes;
- the anomaly appeared to be due to high pressure, not low material strength;
- rust in the interior is localized and deep which may have indicated that it existed prior to the deployment due to a high interior moisture; and
- rust appeared next to the crack surface, but not on the crack surface, supporting the theory that the interior rust likely existed prior to the event.

Picture from a U.S. Engineer's June 13, 2005 Analysis



Assuming the rust existed prior to deployment, the engineer concluded that the event could be explained by interior moisture that could cause the suspected over-pressurization by degrading the propellant's physical properties, resulting in excessive wafer break-up, high surface area, and subsequent high pressures. Under this hypothesis, the engineer explained that the interior moisture was either: (i) manufactured into the product (wet filter, wet propellant, etc.) or (ii) leaked into the inflator through a compromised seal. In addition to the possibility of moisture intrusion, the engineer identified other factors that also may have caused the observed over-pressurization: (i) excess main propellant (*i.e.*, too many batwings) or (ii) excess booster propellant in the igniter assembly.[17] The engineer noted that no further effort could be conducted because the subject inflator had not been returned for analysis.

C. *November 2007 to December 2009: Takata re-analyzes Event 0 as part of its PSDI investigations*

After Takata received notice from the vehicle manufacturer in the summer of 2007 of three field ruptures of PSDI inflators (Events 1, 2, and 3), Takata's engineers conducted a second review of Event 0. In an August 20, 2007 briefing on the three new rupture events, Takata compared the inflator production dates from the 2007 events (all manufactured within three weeks in October and November 2000) to Event 0, which was manufactured in October 2001. From this comparison, Takata's "tentative conclusion [was] that we likely have a cluster of events from a common cause and an isolated incident [Event 0]."

The company further discussed Event 0 on September 14, 2009, when another, more in-depth analysis was completed. At this point, Takata had already recommended two recalls, the first (November 2008) on a theory of low-density wafers due to moisture exposure during manufacturing, and the second (June 2009) based on a root-cause theory of low-density wafers due to inadequate compression during propellant pressing. In the September 2009 analysis, Takata again concluded that the cause of Event 0 was different from that involved in the recent events based on at least four observations.

First, the Event 0 rupture occurred after just 2.5 years in the field. Other reported events occurred after 6 to 9 years of aging.

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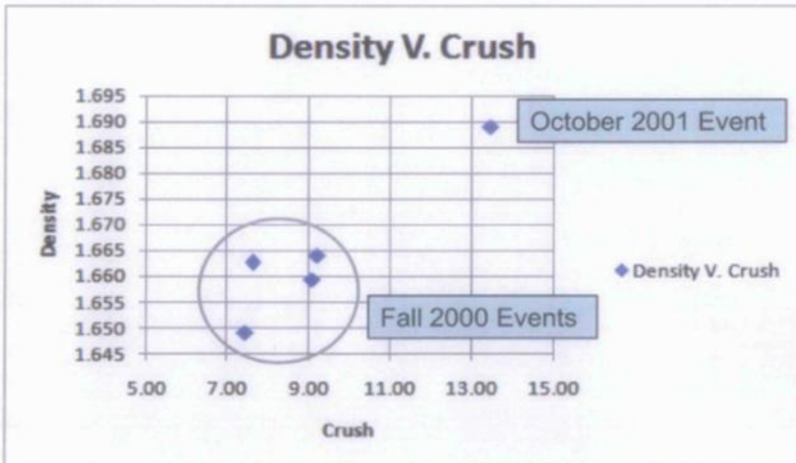
[17] A U.S. engineer in the inflator production group also identified inadequate outlet area as a potential factor for the gas to exit the inflator, but observed there was no evidence to support this explanation because all outlet holes appeared to be present.

Second, unlike the other ruptured inflators, the Event 0 inflator had heavy localized rust. Because the rust was localized to the area around the tape seal of the inflator, Takata engineers hypothesized that the cause of the rust was due to a compromised seal on the inflator—not the presence of moisture introduced during manufacturing. No similar rust pattern had been seen on the other inflators involved in field ruptures.

Third, after testing other inflators from the Event 0 lot, Takata found that the density and other wafer characteristics were excellent—consistent with the best 25 percent of all lots Takata had measured—and above specification. Moreover, ballistics tests on five inflators from the Event 0 lot confirmed no evidence of aggressive characteristics. Propellant characteristics from the Events 1-4 lots, by comparison, exhibited poor density, extreme ballistic variability, and poor propellant performance (*see* comparison below).



1. *October 2009: Takata's testing supported a faulty tape seal as a potential root cause of Event 0*

In October 2009, Takata tested a hypothesis that Event 0 was due to post-manufacturing moisture intrusion caused by a faulty tape seal—rather than moisture introduced during manufacturing. To do so, Takata pierced a hole in the tape seal of a PSDI inflator to provide a leak path for moisture, and then exposed that inflator to high humidity. For comparison purposes, a normal inflator (not subject to additional moisture) was also exposed to the humidity. When ignited, neither the control nor the pierced inflator ruptured. Takata concluded that the lack of an inflator rupture in the pierced unit was likely because no thermal cycling had occurred and thus there was no damage to the wafer despite moisture intrusion. Takata then removed the caps from both inflators to observe the rust patterns. The company found that the pierced inflator had significantly more rust than the normal inflator and that the rust pattern on the pierced inflator was similar to Event 0's rust pattern. This finding, Takata suggested, supported the conclusion that Event 0 was due to a post-manufacturing moisture leak.

2. *November 2009: Internal analysis by a Takata engineer proposed an alternative hypothesis for Event 0*

In November 2009, a Takata propellant engineer and his team conducted additional testing regarding the density of the propellant lot that was used in the Event 0 inflator. They checked the average propellant density of samples from the lot visually and through the use of a scanning electron microscope. The engineer found that some of the wafers in the Event 0 lot had very low density, and one sample had deteriorated. The engineer hypothesized that the low-density wafers had passed manufacturing quality checks because the other wafers in the lot were higher density.

In December 2009, the engineer presented his findings regarding the density of broken batwing wafers in the Event 0 propellant lot, and he concluded that batwings were not being measured for density if they were broken. The engineer noted the possibility that the press operator at the time the Event 0 lot was produced was not experienced with the production of batwing wafers.

The engineer's analysis also included testing to determine the effect of low-density batwings on the PSDI's chamber pressure. Two tests were conducted: one to test the change in pressure as the density of a single wafer drops, and the other to test the change in pressure as the number of low-density wafers in a given PSDI inflator increases. The results showed increased chamber pressure, including the potential for rupture, with a decrease in wafer density.

The engineer's theory concerning low-density batwing wafers was inconsistent with Takata's earlier theories regarding the possible explanations for Event 0. At the time of the engineer's analysis, the recall range for vehicles equipped with the PSDI batwing inflator included only propellant pressed with the Stokes press prior to February 28, 2001, and thus did not include the Event 0 lot, which was pressed in October 2001. However, the recall was expanded just one month later, in January 2010, to cover all PSDI inflators pressed on the Stokes press, which would have included the Event 0 inflator.

VII. 2007 to 2008: PSDI Field Ruptures and the First Recall

A. *July to September 2007: Takata learns of and investigates field Events 1 to 3*

Events 1 and 2 occurred on February 9, 2007 in Arizona and on May 29, 2007 in South Carolina, when PSDI inflators ruptured in two vehicles.

Takata launched its analysis into Events 1 and 2 in June 2007, the same month it received notice of the events from a vehicle manufacturer. Takata provided its first briefing to the vehicle manufacturer on July 23, 2007. As part of its initial observations, Takata highlighted that the two inflators involved were produced within one week of each other—between November 9 and 15, 2000. Takata reported that there was no evidence of issues in the traceability[18] data for the module or the inflator process, *i.e.*, there was no evidence of gaps or problems along the production line. For that reason, Takata's initial fault tree analysis ("FTA") indicated that the focus of the investigation would be on the structural strength (of the cap) and on whether there was excessive burning pressure (of the propellant).

One week after this initial meeting, on July 31, 2007, Takata provided an updated information review to the vehicle manufacturer. Takata stated that there were "no issues noted" in the validation reports for the relevant driver inflators.

Takata had also attempted to reproduce the failure from the field events using engineering samples. It reported that the addition of extra propellant (¾ of a wafer) yielded a result that resembled the field events.[19] However, Takata cautioned that the excess wafer was just one way of generating high pressure and that excess propellant was not the presumed fault. Through an initial analysis of a returned inflator from a relevant production lot (provided by the vehicle manufacturer), Takata also identified certain factors that did not, or likely did not, contribute to the field events:

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[18] Takata records "traceability data": data that tracks the production history of the inflator along the manufacturing chain, with time stamps when each production operation (*i.e.*, propellant into the press) was started and stopped.

[19] Takata's representative testing confirmed that the presence of one additional wafer resulted in a more severe failure mode than observed in the field event.

(i) ***Improper weld fusion*** or ***inadequate crimps*** on the cap structure, since they were both intact,

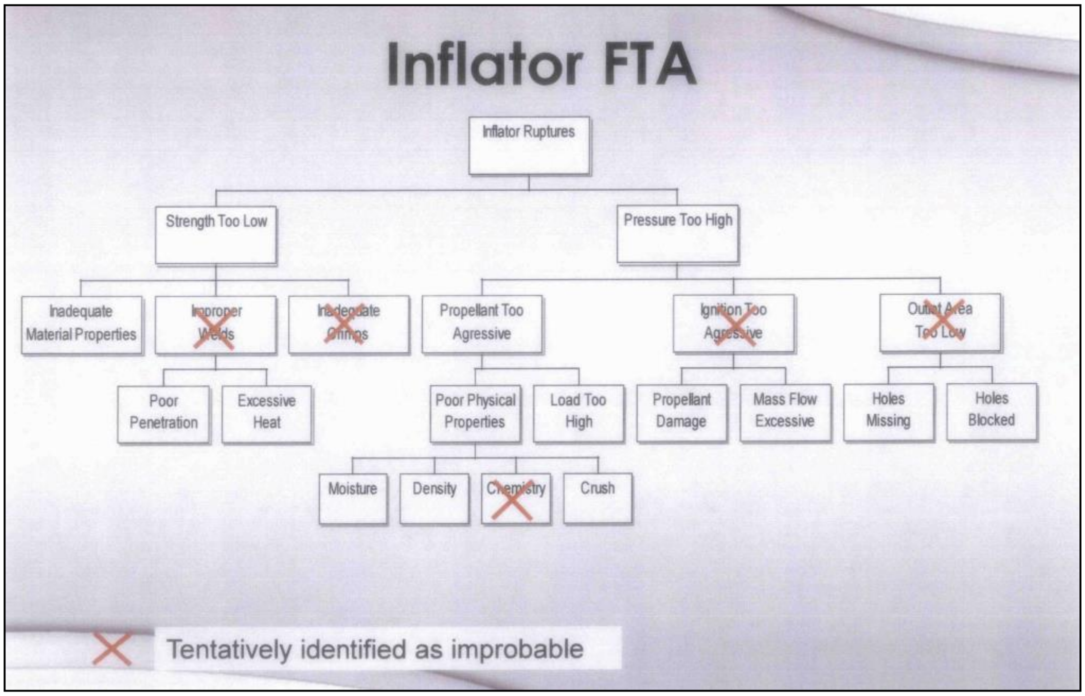
(ii) ***aggressive ignition system,*** since there was no bulging over the ignition chambers,

(iii) ***blockage of the gas outlet***, since outlet holes were in conformity in size and location,

(iv) ***propellant chemistry*****,** since the production history record showed the part was within specification.

The FTA again showed the remaining potential causes as either insufficient cap structural strength or overly aggressive propellant during deployment, which could result from poor physical properties or too high of a load.

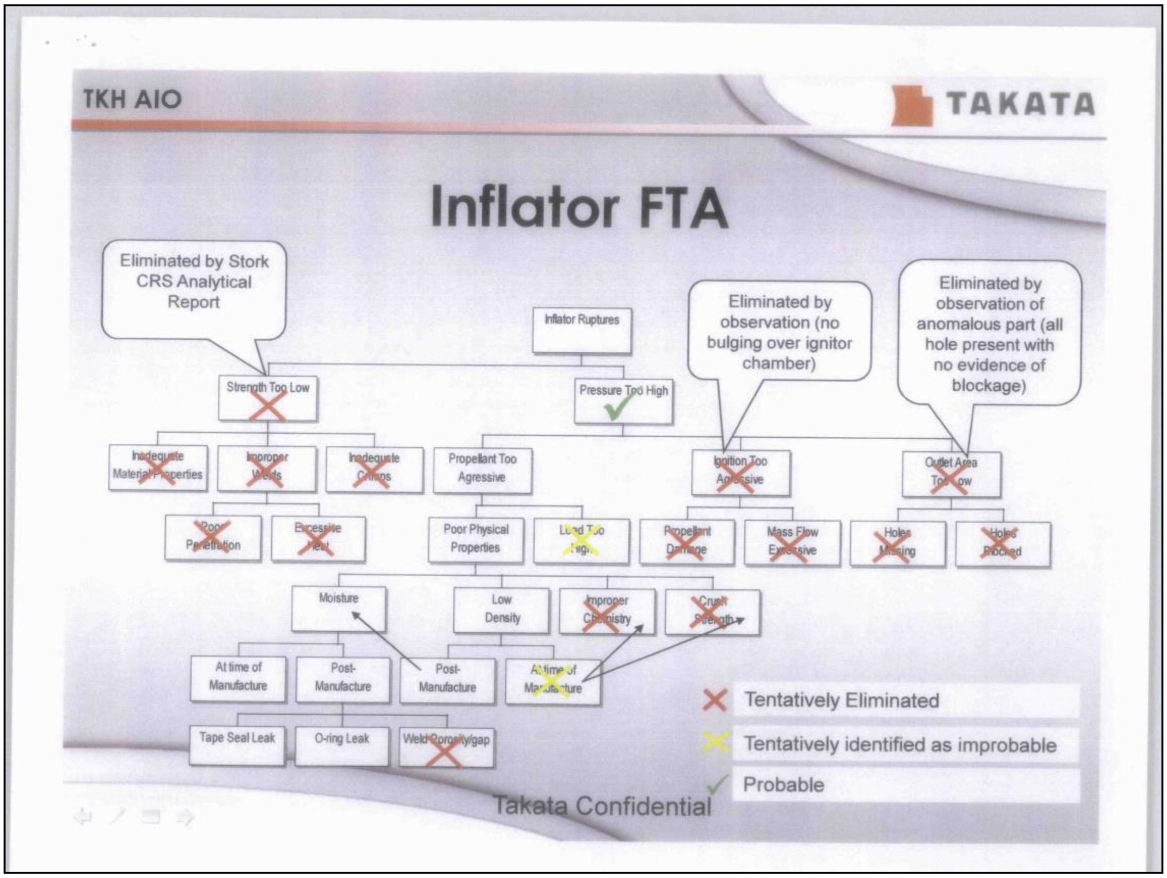
Fault Tree Analysis as of July 31, 2007



In August 2007, Takata learned of another PSDI inflator rupture (Event 3), which occurred in a vehicle in Puerto Rico on May 12, 2007. The inflator from this event had been manufactured on October 31, 2000, within 20 days of the inflators from Events 1 and 2. Takata referenced this event in its August 20, 2007 briefing to the vehicle manufacturer and compared the inflator production dates from the 2007 events to the Event 0 inflator, which was manufactured in October 2001. From this comparison, Takata's "tentative conclusion [was] that we likely have a cluster of events from a common cause and an isolated incident [Event 0]."

During the August 2007 briefing, Takata presented the chemical/metallurgical analysis conducted by an outside research organization of a fractured piece from an event inflator. The analysis concluded—based on the absence of material defects and the inflator's conformance with specification—that the part fractured because it "experienced force . . . that exceeded its load-bearing ability." Based on the analysis from the outside research organization, Takata tentatively eliminated the strength of the cap as being a possible cause of the rupture and identified the probable root cause as excessive burning pressure:

Fault Tree Analysis as of Aug 20, 2007



As the above chart shows, at that time, Takata identified low density as a potential root cause of the aggressive propellant. Takata stated that the most likely cause of the low density was degradation of the propellant through moisture intrusion occurring after the production of the propellant. At this point, Takata had “tentatively concluded” that the low density at the time of propellant production was “unlikely” because “wafers 100% inspected for weight and height at propellant manufacturing site eliminates low density wafers.”

B. *September to October 2007: Takata develops a preliminary causation hypothesis of low density caused by moisture exposure after propellant production*

Shortly after learning of Events 1 and 2, in July 2007, Takata had begun a recovery from salvage yards of PSDI airbag modules from the same makes and models as the Events 1 and 2 vehicles. The purpose “was to look for any evidence of issues with the inflators” manufactured near and after the anomalous inflators. Takata recovered 43 modules, which had been manufactured between June 2000 and September 2002. All the modules were photographed in the condition received, had traceability data verified, and had CT scans conducted to make sure there were no abnormalities. Takata proposed a “teardown” analysis of about half of the salvage samples to check for high moisture or low density in wafers and deployed the other half (22). For the deployment testing, the modules were deployed in a steering wheel at 21ºC. For the “teardown” analysis, Takata dissected the inflators, photographed the parts, and conducted humidity, density, and crush strength tests on the extracted wafers.

In two briefings in September 2007, Takata presented its analysis from the salvage yard sample collection. No issues were identified. The inflators had all passed the helium leak tests,[20] which confirmed the integrity of the hermetic seal.[21] It was believed that having the seal intact meant that moisture intrusion, if any, could not have occurred after the inflator was manufactured.[22] All deployments were normal and post-deployment examination found no abnormal conditions in the inflators. For the inflators that were dissected, the 2004 propellant moisture and density readings were within specification.

Takata also reviewed with the vehicle manufacturer a series of moisture gain studies it had conducted, *i.e.*, the amount of weight gained by propellant wafers when exposed to certain levels of relative humidity. The studies showed a moisture gain of 0.13 wt. percent over a period of approximately 24 hours when exposed to 50 percent relative humidity. The moisture studies also showed that the crush strength—an indicator of propellant performance—declined as the percentage of moisture of the propellant increased, with the largest decline occurring when moisture increased from approximately 0.22 wt. percent to over 0.30 wt. percent.

After introducing this data, Takata presented its preliminary causation hypothesis: The propellant in the inflators had degraded due to compounded moisture exposure during manufacturing. Takata had earlier explained that "regardless of the mechanism of density loss, the effect is the same. Lower density results in lower strength that allows the propellant to break down more during ignition, resulting in high pressures and ultimately rupture." In presenting its causation hypothesis, Takata showed that a moisture level below 0.20 wt. percent (the 2004 specification) and density above 1.68 g/cc put the propellant in the "OK" range. Any density around the 1.65 g/cc or less was identified as "NG" (meaning "no good" or "not good"). Takata had previously noted that no durability test anomalies had been attributed to propellant with moisture levels at 0.20 wt. percent or below, but anomalies had been observed at moisture levels above 0.30 wt. percent.

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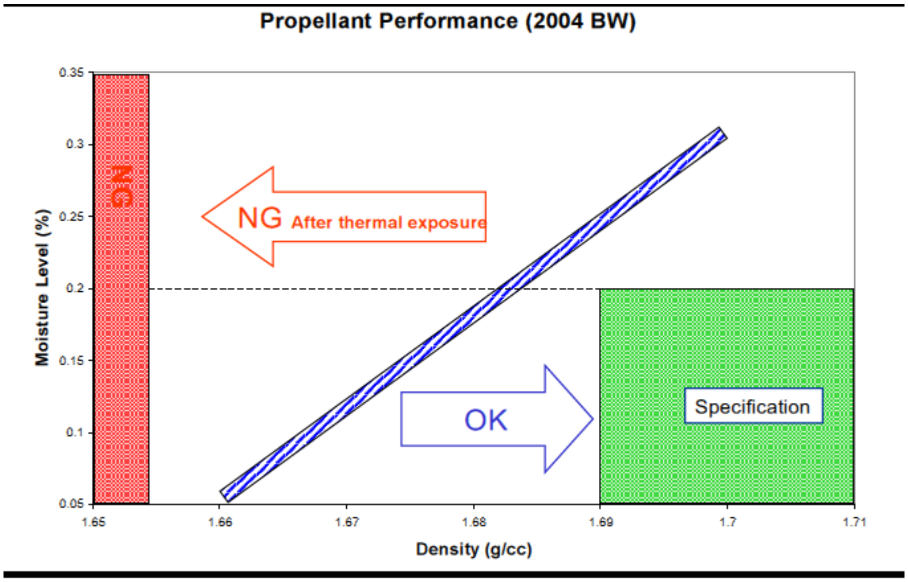
[20] For the helium leak test during manufacturing, the inflator would be placed in a room and the helium content in the room would be measured. Helium would be injected into the inflator, and if there was a higher than normal helium count, then there was a helium leak. Takata used Fourier Transform Infrared Spectroscopy to confirm the internal helium concentration level at the time of dissection.

[21] Review of the production documentation had shown some issues with helium leak and weld issues during the period of the clustered events, which had led to high levels of scrapped product. The trend data, however, showed that the helium leak problems were associated with the cap production lot (which differed among the event inflators) rather than the propellant lot. Similarly, the data did not show any trend that related to the welding of the units.

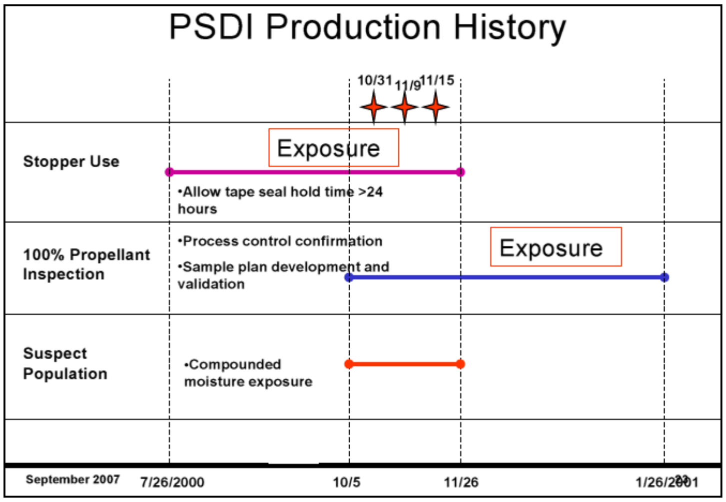
[22] Helium atoms are smaller than water molecules. Since there were no helium leaks with the inflators analyzed, the seal was good and the belief was that water did not intrude into the inflators after they were manufactured.

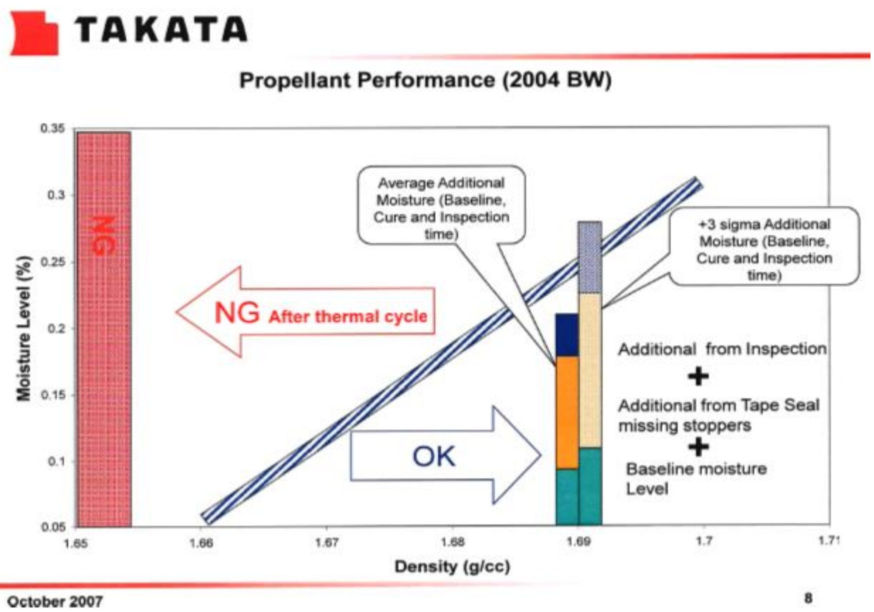


Through review of the production data, Takata had identified two unusual process conditions at the time the event inflators were manufactured that could have contributed to the compounded moisture. First, during the period of July 27, 2000–November 26, 2000, the LaGrange plant implemented a tape seal hold, such that inflators assembled and welded on one day were held for a minimum of 24 hours to allow the tape seal to harden or "cure" before the helium leak check. During that hold time, a stopper was placed at the end of the inflator instead of an igniter plug being inserted and crimped. Takata believed that openings in the stopper might have exposed the propellant to higher levels of moisture. Second, during the period of October 5, 2000–January 26, 2001, Takata was inspecting all PSDI batwing wafers manufactured at Moses Lake for height and density. This 100-percent inspection period permitted unexpected levels of moisture exposure.

All three of the event inflators from 2007 (Events 1-3) were manufactured during the overlapping period when both the tape seal and the 100-percent inspection processes were in place. Takata believed the abnormal moisture exposure from both processes—when combined with normal vehicle operation that exposes the inflator to thermal cycling over time—could lead to sufficient degradation to trigger a problem. Takata advocated further investigation to confirm that excessive moisture could cause the inflator ruptures observed in the field.[23]

[23] At the same time Takata was presenting its hypothesis to a vehicle manufacturer regarding the tape-seal hold and 100 percent propellant inspection, an internal presentation analyzed the amount of inflators that contained milled BHT and were involved in the 24-hour tape-seal hold. It is unclear whether Takata ever raised the milled BHT issue with the vehicle manufacturer in these initial meetings, but none of the inflators involved in the first three events contained milled BHT, which likely explains why this information was not in the technical presentation.





C. *October 2007 to September 2008: Takata tests the moisture hypothesis*

Throughout the fall of 2007, Takata tested its compounded moisture hypothesis, which posited that (i) abnormal moisture exposure during production combined with (ii) the thermal cycling that occurs as part of normal vehicle operation resulted in the increased pressure output that resulted in the field ruptures. As part of Takata's induced moisture testing ("moisture matrix") to confirm this hypothesis, Takata added moisture at levels of 0.05 wt. percent, 0.15 wt. percent, and 0.25 wt. percent to inflators and subjected them to one-half and full high temperature aging, as well as thermal cycle testing. The testing also occurred at different temperatures—room temperature, 25ºC, and 85ºC.[24]

[24] For moisture measurement, Takata used the Karl Fischer method. It has been explained as "a technique to determine the concentration of a substance in solution by adding to it a standard reagent of known concentration in carefully measured amounts until a reaction of definite and known proportion is completed, as shown by a color change or by electrical measurement, and then calculating the unknown concentration." *See Moisture Determination*

Takata presented the results of all of the different variable permutations from the moisture matrix to the vehicle manufacturer on November 2, 2007. Takata found that the inflators showed "increased aggressiveness" with increasing moisture and increasing exposure times to environmental conditioning. Specifically, Takata concluded that inflators with approximately 0.22 wt. percent or lower of initial moisture showed only "slight degradation" and maintained normal performance characteristics. However, the ballistic data at 85ºC, with 0.25 wt. percent added moisture and full thermal cycling, presented the "worst case scenario," demonstrating an internal chamber burst pressure at approximately 1.5 times that of the baseline unit and resulting in potential disassembly during operation.

During the November 2, 2007 presentation, Takata once again reiterated that it considered "Event 0" (the rupture from 2004) to be distinct and not associated with the potential problems found in the other inflators being analyzed.

In addition, in the November 2, 2007 presentation and a follow-up teleconference on November 29, 2007, Takata estimated approximately 90 days for production of replacement inflators and outlined the inflator replacement procedure. In the follow-up teleconference, Takata also responded to the vehicle manufacturer's request for a statistical risk analysis in the event it did not conduct a field action. Takata estimated that, assuming the failure rate of inflators in the relevant population was constant, there was a risk that 3 to 5 more events might occur in the next eight years.

On January 22, 2008, Takata again met with the manufacturer. According to Takata, the manufacturer believed that Takata's moisture hypothesis—that more than 0.32 wt. percent moisture was absorbed in the inflators—included too many assumptions and was likely not realistic. Takata noted that an American vehicle manufacturer had previously had a similar issue of inflator breakage and it solved the problem by collecting and analyzing modules from the lot using the same propellant as the problematic ones.[25]

Takata advocated for a field study of inflators from the same lots of propellant as the three ruptured inflators ("healthy car analysis"). The purpose was to assess whether the root cause assumption was correct and to confirm that the analysis was targeting the right population of inflators. Takata sought to recover 85 inflators, with 70 for deployment and 15 for dissection to test moisture. Takata later explained that if any failures occurred in inflators with moisture levels less than 0.32 wt. percent, the potential recall action would need to expand beyond inflators manufactured near the event lots.

From the period of approximately March to July 2008, the vehicle manufacturer recovered 86 inflators from these event lots. Takata's analysis included dissecting the inflators and evaluating the batwing propellant for gloss, hardness, crush/strength, dimensions, and density. Out of the 66 inflators given the helium leak test, all passed, a result that Takata believed foreclosed the possibility of moisture intrusion after manufacturing. However, as compared to non-event lots, the propellant from the event lots had less gloss, less hardness, less crush/strength, and less density—all factors that could signal degraded propellant performance. Of the 19 inflators deployed from event lots, two resulted in an "energetic disassembly," or inflator rupture. Takata believed these disassemblies and the different characteristics of the propellant lots confirmed its hypothesis of excessive moisture exposure during manufacturing.

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by Karl Fischer Titration, available at http://www.sigmaaldrich.com/content/dam/sigma-aldrich/docs/Supelco/Posters/1/understanding-kf-090810.pdf.

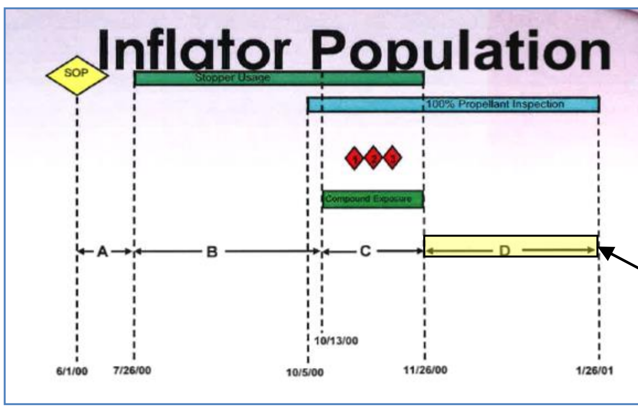
[25] The subject inflator in the incident was manufactured by a supplier other than Takata at a Florida plant and the propellant had absorbed moisture from abnormal exposure in the production environment.

D. *September to October 2008: Takata recommends a limited recall, while a new field event challenges the prevailing moisture hypothesis*

1. *Field Event 4 is not explained by Takata's prevailing moisture hypothesis*

On September 11, 2008, Takata was informed of an additional field rupture that had occurred in a vehicle in Texas on January 27, 2008. The inflator had been manufactured on December 1, 2000, during the 100-percent inspection period and within a month of the three inflators from Events 1 to 3. However, the inflator from Event 4 was manufactured outside the tape seal/stopper application period and thus did not fall within the population of inflators covered by Takata's then-prevailing hypothesis.

Takata's moisture hypothesis prior to Event 4 had assumed (i) baseline moisture at 0.08 wt. percent when the propellant was manufactured, (ii) moisture increase of approximately 0.04 wt. percent during the 100-percent inspection period, and (iii) potential moisture increase of up to 0.25 wt. percent during the stopper application/tape seal period. Under these calculations, Takata surmised that inflators manufactured during the stopper application period alone, or more likely, during the combined stopper application and inspection period, could result in a moisture level above 0.32 wt. percent that could degrade the propellant. Takata had not believed, however, that inflators subject only to the 100-percent propellant inspection—like Event 4 and in "D" below—could exceed the 0.32 wt. percent moisture threshold.



Population		*Shipped to N.A.	**Shipped to TKJ	Total Shipped
A	Total	1815	15699	17514
	>0.32	0	0	0
B	Total	82226	35929	118155
	>0.32	8844	2206	11050
C	Total	93412	19518	112930
	>0.32	36431	4413	40844
D	Total	69922	16510	86432
	>0.32	0	0	0
TOTAL		247375	87656	335031

2. *Subsequently, Takata recommends a limited recall*

In early October 2008, Takata provided more comprehensive findings on the moisture/thermal cycling hypothesis, including data from the healthy car analysis testing. Takata again reported that the most likely cause of the events was degraded propellant resulting from moisture intrusion during the manufacturing process and temperature cycling.

The October 2008 presentation estimated that the calculated moisture for the three event lots from 2007 all exceeded the 0.32 wt. percent threshold. Takata again eliminated moisture intrusion occurring at the propellant manufacturing stage as the sole cause. It pointed to possible moisture intrusion at the time of inflator manufacturing, highlighting manufacturing procedures related to (i) the propellant break-down room, (ii) in-plant material handling, (iii) the propellant load station, and (iv) stopper application. While earlier presentations had pointed to the 100-percent inspection of propellant for weight and density as a source of moisture exposure, this cause was not specifically mentioned in the October 2008 presentation.

Based on its investigation, Takata proposed that the vehicle manufacturer replace inflators containing propellant from the same lots as the four field events. However, Takata believed that further investigation and analysis was necessary to determine the root cause of the field events. Because the four event inflators were manufactured in the period from October 31, 2000 to December 1, 2000, Takata also recommended that the manufacturer recover inflators from propellant lots manufactured before, after, and during the time period that the four event inflators were manufactured (October 31, 2000 to December 1, 2000) that could be analyzed and studied. Takata proposed evaluating the propellant in these "surveillance inflators" through an analysis of five characteristics—gloss, hardness, crush/strength, dimensions, and density (the characteristics developed during the healthy car analysis project)—and expanding the replacement activity to any lot of an inflator that did not pass.

3. *The vehicle manufacturer proceeds with Recall No. 08V-593*

After considering Takata's recommendation, the vehicle manufacturer decided to proceed with a safety recall, and on November 11, 2008, it gave NHTSA notice that it was recalling approximately 3,940 units from model year 2001 vehicles—with limited manufacture dates between late October 2000 and March 2001. The vehicle manufacturer's defect description stated that the driver airbag inflator could "produce excessive internal pressure . . . [that] may cause the inflator to rupture. Metal fragments could pass through the airbag cushion material possibly causing injury to vehicle occupants."

VIII. January 2009 to February 2010: Additional Ruptures

A. *January 2009 to June 2009: Takata analyzes surveillance inflators from Recall No. 08V-593 and manufacturing records from newly ruptured inflators from outside the recall range*

In January 2009, Takata began to analyze inflators returned from surveillance lots, which are lots manufactured around the same time as the inflators that were involved in Events 1-4. Takata dissected the propellant from these surveillance inflators and analyzed five characteristics: gloss, dimension, density, strength, and hardness. During a March 12, 2009 meeting with the vehicle manufacturer, Takata stated that it had received 166 inflators from 118 of the 207 surveillance lots. Takata had identified four lots that warranted further analysis.

On or around May 29, 2009, Takata learned of a PSDI rupture in a vehicle in Oklahoma ("Event 5"). The inflator had been manufactured on October 12, 2000 and was outside the range covered by the 2008 recall. During communications with the vehicle manufacturer in early June 2009, Takata reviewed the manufacturing records for Event 5 and noted that the inflator had an unusual time delay of 3.5 hours between two particular inflator manufacturing processes when 6 minutes was typical. Takata hypothesized that this delay could have exposed the secondary chamber propellant to uncontrolled plant air for 3.5 hours. The inflator at issue in Event 5 was the first inflator in an event to have contained milled BHT. Up to this point, Takata had not included milled BHT as a potential factor in its root cause analysis.

On June 9, 2009, Takata learned of a PSDI rupture in a vehicle that had occurred in Florida in April 2009 ("Event 6"). That inflator also had been manufactured outside the 2008 recall range. Takata informed the vehicle manufacturer that the inflator in Event 6 did not have any of the unusual time delay seen in the inflator in Event 5. As a result, that hypothesis was no longer viable. In addition, Takata told the manufacturer that the data from the recalled inflators showed measurements consistent with the 85 inflators returned from the healthy car analysis in 2008.

B. *May 2009 to June 2009: In investigating Events 5 and 6, Takata's hypothesis for ruptures shifts to the propellant lot hypothesis, which focuses on the production of the propellant*

Due to additional field events and its ongoing analysis of the surveillance inflators received from the 2008 recall, Takata reconsidered the compound moisture hypothesis. Analysis of the returned inflators showed potential trends associated with equipment used during propellant production, leading Takata to investigate the presses on which propellant was produced.

Takata employed two types of propellant press machines to manufacture the propellant used in inflators involved in the field events: the Gladiator press (which had three models) and the Stokes 340 press. The Stokes press, which had been purchased and used for research and development in Armada, Michigan, was transferred to Moses Lake and used as a production press in the initial period of PSDI production. Although the Stokes press was not equipped with a complete set of quality-control features found in production presses, it was used to manufacture the 2004 propellant batwings until October 16, 2001. After that date, all batwings were produced on Gladiator presses.

Takata presented its new findings on the propellant press issue to the vehicle manufacturer in the summer of 2009. Takata was able to identify trends associated with the propellant press equipment because of the data Takata had at its disposal through surveillance inflators gathered during the 2008 recall. Consistent with its analysis that preceded the 2008 recall, Takata emphasized that lower density results in lower strength that allows the propellant to break down more during ignition, causing more surface area, faster burn rates, higher gas pressure, and, potentially, the possibility of a rupture. Takata's analysis showed that the density and crush strength of the propellant wafers were dependent on the type of compaction press used to produce them. Propellant wafers made by the Gladiator 1 press exhibited higher density and crush strength than those made by the Stokes press. As a result, 64 of 69 lots made with the Stokes press between mid-October through December 2000 were considered potentially problematic. But Stokes-pressed propellant did show a significant increase in density over time, with density improving in late 2000 and trending at that point towards target levels.[26] Takata's analysis further showed that reprocessed propellant made on both presses was lower in density than "virgin" material, though its crush strength was higher and not correlated to density.[27]

Further, Takata noted that the propellant lots from the seven events (Events 0 through 6) were believed to be made on the Stokes press, with the possible exception of the lot from Event 6. Unlike the Gladiator press, the Stokes press did not apply pre-compaction force to the propellant before the final compaction, which Takata hypothesized might have been one factor that contributed to the low density.

As a result of its findings, Takata concluded that the root cause of the events was likely related to a press-specific degradation of propellant. While Takata still believed the excessive internal pressure in the field events resulted from aggressive propellant due to low density, at this point in its investigation, it refocused its root cause investigation on the production of the propellant rather than on the handling of the propellant during inflator manufacture.

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[26] The density measurement techniques available to Takata made it difficult to evaluate the density of batwings. A point of thickness measured at the center of a batwing did not—and could not—reveal the thickness of a batwing at its "wing ends."

[27] Until mid-October 2000, Takata occasionally produced propellant wafers with recycled propellant material from rejected wafers.

C. *June 2009 to July 2009: Takata recommends expanding the PSDI recall based on the type of propellant press used to create propellant wafers in certain inflators*

During the June 12, 2009 presentation, Takata recommended to the vehicle manufacturer that it expand its 2008 recall to include inflators known to have a lower density. Takata recommended recalling inflators containing:

(i) Stokes-pressed propellant produced from June 1, 2000 (start of production) through February 28, 2001, the date identified as sufficient to capture propellant at risk of low density;

(ii) Reprocessed propellant; and

(iii) Gladiator 2-pressed propellant that showed substandard density.[28]

As with the 2008 recall, Takata also recommended using the recall process to request that approximately 10,000 additional vehicles with non-recalled inflators manufactured between October 18, 2000 and November 26, 2001[29] be covered by the campaign so that those inflators could undergo further analysis. For inflators outside the target range, Takata could assess whether the defect determination had captured all problematic inflators and to determine the effect of process improvements on Stokes propellant. The vehicle manufacturer agreed with this recommendation to expand the 2008 recall.

On June 30, 2009, the vehicle manufacturer informed NHTSA in a Part 573 Defect Information Report ("DIR") of the potential defect and identified the affected 2001-2002 model year vehicles. On July 29, 2009, the vehicle manufacturer notified NHTSA that the recall, identified as Recall No. 09V-259, covered approximately 440,000 vehicles.

D. *July 2009 to September 2009: Additional PSDI ruptures and NHTSA discussions*

Between approximately July 29, 2009 and September 19, 2009, Takata learned of four additional PSDI ruptures (Events 7 through 10). Each of these four events contained propellant made by the Stokes press during dates covered by Recall No. 09V-259.

On August 19, 2009, NHTSA's Office of Defects Investigation ("ODI") sent a letter to the vehicle manufacturer requesting additional information to "understand why [the manufacturer] did not include the current population [of Recall No. 09V-259] in [Recall No.] 08V-593, and to evaluate the timeliness of [the manufacturer's] recent defect decision." Further, the letter inquired whether the manufacturer was "certain that it has identified and made a defect decision as to all of its U.S. vehicle products that could contain the defect identified in [Recall Nos.] 08V-593 and 09V-259."

On September 16, 2009, the manufacturer responded to NHTSA's eight separate questions. The manufacturer clarified that there was no difference between the inflators involved in the 2008 and 2009 recalls, explaining that it now believed that the causal factors were related to the production of the inflator propellant (rather than the handling of the propellant as it had hypothesized at the time of the 2008 recall). The manufacturer stated that it believed the

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[28] The Gladiator 2 press was infrequently used and there were only three lots of Gladiator 2 propellant that were examined as part of the surveillance lots obtained through the 2008 recall. Of the three lots examined, each was found to be potentially problematic, and the decision was made to include all driver-side inflators containing Gladiator 2-pressed propellant as part of the 2009 recall.

[29] During this period of time, (i) propellant had been pressed on the Stokes press, and (ii) propellant pressed on the Gladiator 2 press had exhibited substandard density.

"cause to be related to the process of pressing the propellant into wafers," and that the current recalls "included all vehicles that could be affected by this defect."

E. *August 2009 to October 2009: Takata enlists independent experts to investigate root cause*

In late August 2009, Takata convened an independent team of experts to examine (i) the root cause of the problem(s) that led to the affected vehicle manufacturer's recalls, (ii) the chemistry and effects of aging on Takata's PSAN propellants, and (iii) the robustness of Takata's propellant manufacturing process. As part of this effort, Takata began to contract for outside expert review by Fraunhofer and Baker Engineering and Risk Consultants, Inc. ("BakerRisk").[30]

F. *August 2009 to December 2009: Takata's root cause investigation focuses on compaction force of propellant presses*

1. *Takata identifies the propellant press as a potential cause of low density*

With both the 2008 and 2009 recalls, Takata's working root cause hypothesis was that the event propellants were overly aggressive due to low density. By 2009, it was well-known that in propellants and pyrotechnics, as density decreases, burn rate increases and gas is generated more quickly, which results in an increase in internal inflator pressure.

Takata's continued investigation of the surveillance inflators in the fall of 2009 focused on the root cause mechanism of low density in the propellant wafers. In a meeting in early September 2009 with a vehicle manufacturer, Takata identified and analyzed three possible reasons for low density in the propellant: (i) excessive moisture, (ii) chemical bonding, and (iii) mechanical bonding (including pressing of the propellant).

Takata ruled out excessive moisture resulting from exposure during manufacturing because the moisture measurement record (before the inflators were shipped to the vehicle manufacturer) from the propellant lots of some of the event inflators was found to be within acceptable levels. Takata also ruled out excessive moisture resulting from moisture absorption in the field because analysis of the event propellant lots illustrated that moisture was within the acceptable range and the seal was intact.

Next, Takata eliminated chemical bonding as a root cause of the low density because (i) deterioration of the propellant was not seen, (ii) the composition of propellant did not have any problems, and (iii) there were no foreign substances found in the propellant. Takata also found that particle size distribution did not deviate during production and eliminated variation of particle size as a potential cause for inflator rupture. Having eliminated excessive moisture and chemical bonding as root causes, Takata's attention turned to whether a failure of the pressing process led to the low density.

2. *Takata evaluates the pressing process*

In the latter part of 2009, and in a series of presentations to the vehicle manufacturer, Takata considered and examined a series of factors related to the pressing process and the various presses used:

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[30] BakerRisk describes itself as "an internationally recognized firm dedicated to help predict, prevent, and mitigate hazards from explosions, fires, and toxic releases" specializing in "process safety and risk management services to companies in the petroleum and chemical industries, as well as engineering and testing services for government agencies and private companies involved with hazardous materials." About Us – BakerRisk, http://www.bakerrisk.com/about-us/ (last visited June 29, 2016)

- ***Pressing or Production Speed***: Takata considered whether the amount of time that pressure was applied ("retention time") during the pressing process was the cause of low density. Retention time changed if the pressing speed was altered, and the Gladiator and Stokes presses had different production speeds. Testing, however, showed that the propellant production speed difference did not ultimately change the inflator housing's internal pressure and thus was not a cause.

- ***Availability of Pre-Compaction Load***: Unlike the Stokes press, the Gladiator press had a "pre-compaction" step that applied 10-30 percent of the force of the final compaction step and served to remove air. Takata examined whether the absence of the pre-compaction step in the Stokes press was a cause of low density and, potentially, the ruptures. Takata concluded that pre-compaction did not directly influence the potential for rupture.

- ***Main Compaction of Propellant***: Takata also evaluated both the effects of the amount of main compaction force during propellant production and how the pressing process was affected by the amount of propellant powder. As to the former, testing showed that density increased with increasing force. As to the latter, testing confirmed that if the quantity of powder was smaller, the force was decreased and thus the density was lower.

3. *Takata focuses on low compaction force and inadequate density measurements as contributing factors*

In identifying compaction—either because of inadequate force on the press or due to low fill—as the underlying issue, Takata's hypothesis was that the low compaction load allowed the formation of gas pathways in the propellant and increased burn rates. As a result, Takata hypothesized the combustion speed could become excessively high during ignition and thus could break the inflator housing. This hypothesis was consistent with data correlating propellant density with press type, since the Stokes press did not control compaction load and was not equipped with an auto-reject function for wafers outside the desired density range. With the Stokes press, a sample of the wafers (approximately 4 out of 600-750) was manually inspected for density and weight. If the sampling inspection showed that wafers were out of specification, then the operator manually adjusted the compaction load.

Unlike the Stokes press, the Gladiator press had automatic measuring of the compaction load and displayed the compression force to the operator, which allowed the operator to see when the force deviated from the specification. Further, while the Stokes press relied on manual inspection, the Gladiator press had an *automatic* reject function that rejected propellant wafers when the measured compaction load was outside the specification. In the event a reduced amount of powder was loaded in the Gladiator, the Gladiator's load auto-adjust and auto-reject functions also could guarantee the compaction load was proper.

Although Gladiator presses were equipped with these automatic functions and feedback, one of the Gladiator presses, "Gladiator 2," had pressed propellant that had lower density wafers, including wafers found in one of the event inflator lots. As a result of many difficulties in operation, the Gladiator 2 press was only used for batwing production for about six weeks.[31] Takata found that premature wear on components and lubrication issues on the Gladiator 2 press made force measurements inaccurate, which allowed propellant to be produced with low

[31] The Gladiator 1 and the Gladiator 2 presses were mechanically the same. The Gladiator 2 was used for batwing process development and thus had much more significant wear. The nature of the batwing—thin wafer with high density requirements—resulted in more frequent machine component replacement.

compaction load. Based on the various equipment problems on the Gladiator 2, Takata added maintenance improvements and inspection checks on the Gladiator 1 and Gladiator 3 presses.

4. *Improvements to the Stokes press did not result in improved density*

The June 2009 recall had extended to inflators with Stokes propellant manufactured until February 28, 2001 because Takata's investigation had shown a tendency for density improvement of Stokes propellant after January 2001. Takata believed that a series of process improvements on the Stokes press implemented in the fall and winter of 2001 had led to improved density that lasted the remainder of the time the Stokes press was used. These process improvements included better propellant powder flow and a longer cure time.

During the fall and winter of 2009, Takata analyzed more than 1,000 "surveillance" inflators recovered through Recall No. 09V-259, *i.e.*, those outside the subject range that were recalled to assess whether the defect determination had captured all problematic inflators and to determine the effect of process improvements on Stokes propellant. Testing showed that inflators from the surveillance range performed properly. However, Takata found that while the density of Stokes propellant had shown some improvement from late 2000 to early 2001, the density stabilized and the average density of Stokes propellant produced after February 28, 2001 remained below specification. Takata eventually concluded, contrary to its earlier hypotheses, that there was no correlation between Stokes process enhancements and density improvements.

G. *January 2010 to February 2010: The vehicle manufacturer expands the PSDI recall to cover all Stokes-pressed propellant (10V-041)*

Takata continued to meet with the vehicle manufacturer through January 2010 to discuss the root cause investigation and results from the surveillance analysis. At a meeting on January 28, 2010, Takata reported that all surveillance inflators had deployed properly and that no ruptures had occurred with propellant made in the surveillance period. Takata stated, however, that it could not obtain effective evidence to prove that there would be no more occurrences in the future from Stokes propellant made after February 28, 2001. Takata explained that "even though the occurrence rate is unpredictable, since this problem is directly related to injury and death, we propose the positive market action [*i.e.*, recall] for the remaining products produced by Stokes." The vehicle manufacturer agreed that its recall in North America should be expanded to cover *any* inflator containing propellant made by the Stokes press (*i.e.*, those produced after February 28, 2001).

The vehicle manufacturer informed NHTSA on February 9, 2010 of an expanded recall. The vehicle manufacturer explained that while no inflators from the expanded range had ruptured, it was concerned that the sampling process and lack of load-monitoring on the Stokes press could have allowed propellant with low density to have been made even after February 28, 2001. The vehicle manufacturer stated to NHTSA that it "[could not] entirely rule out the possibility that parts in this expanded [Stokes] population could be out of specification and thus potentially perform improperly." The recall range now covered all vehicles manufactured with PSDI inflators that contained propellant wafers that, according to Takata's records, were produced by the Stokes press.

IX. November 2009 to May 2010: NHTSA Investigates the First Two PSDI Recalls

A. *NHTSA requests additional information from Takata concerning the recalls to date*

On November 2, 2009, NHTSA opened an investigation "to collect and analyze additional information to better evaluate the scope and timeliness of [the vehicle manufacturer's] two safety recalls addressing rupturing of the driver's side air bag inflators (08V-593 and 09V-259)." Since the vehicle manufacturer had informed NHTSA in September 2009 that it had relied on information from Takata regarding the inflator ruptures, NHTSA issued an information request to Takata on November 20, 2009 to obtain information about "the sources and causes of the safety defect, the steps taken to identify the defect and when those steps were taken, and what and when pertinent information was shared with [the vehicle manufacturer]." The information request consisted of ten questions. Takata provided a preliminary response on December 23, 2009, and provided an updated response on February 19, 2010.

In its February 19, 2010 response, Takata detailed the investigation and analysis it undertook prior to both recalls. It explained how it initially attributed the defect to abnormal moisture exposure during the handling of the propellant coupled with thermal cycling but had revised that hypothesis when additional ruptures and data from surveillance inflators showed the problem likely resulted from problems with one of the propellant compression presses.

NHTSA inquired whether inflators other than those found in the affected manufacturer's vehicles were subjected to the same propellant chemistry or production process. Takata responded that it had "not provided any air bag inflators that are the same or substantially similar to the inflators in vehicles covered by [the recalls] to any customers other than [the affected vehicle manufacturer]. The physical characteristics of the inflator housing used in the [affected manufacturer's] vehicles subject to the[] recalls are unique to [that manufacturer]."

B. *NHTSA closes its investigation*

On May 6, 2010, NHTSA closed its investigation of the recalls. In its summary report explaining the decision to close the investigation, NHTSA stated: "Based upon all available information, there is insufficient information to suggest that [the vehicle manufacturer] failed to make timely defect decisions on information it was provided. Also, given that all inflators with propellant manufactured using the Stokes press have been recalled, there are no additional vehicles to be investigated and campaigned. Accordingly, this RQ is closed."

X. January 2010 to September 2010: Ongoing Investigations Produce Further Findings

A. *Reviews conducted by outside experts in 2010 do not conflict with Takata's causation hypothesis at the time*

In 2010, outside experts BakerRisk and Fraunhofer conducted independent reviews which resulted in no findings in conflict with the causation hypotheses advanced by Takata at that time. As discussed more specifically below, BakerRisk provided initial findings which concluded that Takata's Moses Lake production methods were sound and found no significant issues warranting corrective action. BakerRisk had made two site inspections of Takata's Moses Lake facilities to evaluate whether any practice or procedure existed that could compromise the quality, safety, or aging properties of the 2004 propellant. BakerRisk also independently evaluated sample propellant from Moses Lake and reported on the chemical analysis of the 2004 propellant, concluding that the 2004 propellant was made within specification. In addition, Fraunhofer had begun to analyze recalled PSDI inflators and the propellant they contained. As discussed in greater detail below, Fraunhofer focused upon—and found no issues with—the stability of the chemistry and phase stabilization of the recalled propellant.

B. *March 2010 to April 2010: Outside experts confirm chemical stability of the 2004 propellant*

In a March 2010 report, Fraunhofer shared its interim findings on the chemical stability, phase stabilization, and performance of the 2004 propellant (manufactured in 2000) removed from returned PSDI inflators (which contained batwing propellant wafers) under recall. For comparison purposes, Fraunhofer had also tested newly produced propellant. Fraunhofer's analysis found no significant changes between the recalled propellant and the newly produced propellant. First, the analysis of the internal gases showed no anomalies and no problems with chemical stability. Second, if not stabilized properly, ammonium nitrate can undergo a phase transition at greater than 80ºC that negatively affects density and stability of the propellant. Fraunhofer's testing of the returned batwing wafers showed phase stabilization of ammonium nitrate to at least 100ºC with no deterioration. Third, Fraunhofer had looked for changes in the thermal properties or energetic performance of the propellant, since either factor could indicate decomposition or changes in the chemical state. Fraunhofer reported there was no change in thermal properties or energetic performance of recalled propellant as compared to the new propellant.

In an April 2010 report, outside expert BakerRisk outlined its findings on the chemical stability and aging of the 2004 propellant, the 3110 propellant used in the booster, and the AI-1 auto-ignition material used in the PSDI and other inflators. BakerRisk's report was based on the data from both Takata and tests conducted by BakerRisk and other independent experts, including accelerated aging tests that exposed propellant to elevated temperatures, high temperature decomposition tests, and headspace gas tests on 10-year-old inflators from the year 2000. BakerRisk concluded that the "chemical aging of inflator propellants will not prevent the inflator from functioning as designed." BakerRisk found that the 2004 and 3110 propellants were "highly chemically stable at temperatures and durations relevant for long-term automobile inflator applications." Second, BakerRisk reported that the AI-1 propellant was less thermally stable by design and expected to be partially degraded (10 percent after 10 years), but noted that "there is no evidence" that such partial decomposition after 10 years adversely affects inflator performance.

Both the Fraunhofer and BakerRisk reports were consistent in finding that the 2004 propellant used in the PSDI was highly chemically stable for durations necessary for long-term automobile use. There was no evidence that the chemistry of the propellant had problems with aging or caused any functional problems, such as the event ruptures.

C. *April 2010: Outside experts find no problems at Takata's Monclova facility*

Outside expert BakerRisk conducted a site visit of Takata's Monclova facilities in Mexico from March 31 to April 2, 2010 to survey current propellant handling and inflator assembly. The inspection focused on moisture issues, scrap handling, welding, and identifying whether any procedures could compromise the quality, safety, or aging of airbag inflators. BakerRisk's April 21, 2010 report concluded that Monclova had no major issues needing corrective action and described production methods as "excellent," although a few questions regarding the welding process and weld specifications were noted. In its report, BakerRisk concluded that (i) no problem existed that would significantly increase the moisture content of the propellant during inflator assembly, (ii) the weld quality was good with no evidence that the propellant was affected when some portions of evaluated inflators were exposed to more heat than normal during the welding process, (iii) further investigation may be required to determine whether the lack of an upper or maximum limit on the weld specifications could expose the propellant to excessive high temperatures, (iv) the hydroburst test needed further clarification for when a weld has "passed" or "failed," and (v) there were no issues with helium leak tests performed by Takata.

D. *September 2010: Fraunhofer's initial analyses are consistent with Takata's causation hypothesis that manufacturing problems were the most likely cause of the ruptures*

On September 20, 2010, Fraunhofer issued a report summarizing its test results on phase stability, physical properties, and performance of the 2004 propellant it obtained from recalled PSDI inflators. Fraunhofer's analysis included X-rays of the inflators, leak testing, ballistic testing, dissecting of inflators, measurements of density and moisture in the propellants, and comparisons to more recently produced inflators.

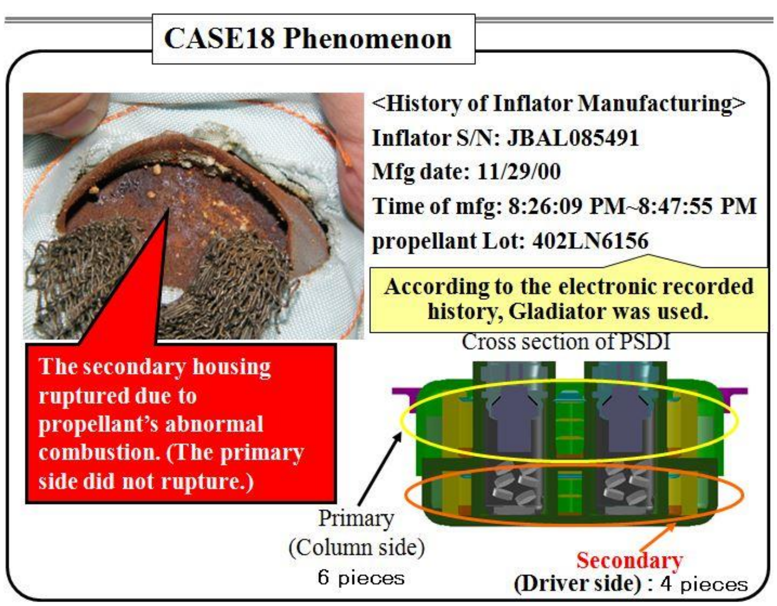
Overall, Fraunhofer's testing showed no significant changes between newly produced propellant and propellant recovered from the recalled PSDI inflators. Fraunhofer's findings included: (i) there was no critical loss of chemical stability of the propellant taken from the recalled inflators, (ii) the density and humidity of the recalled batwing propellant did not differ from newly manufactured propellant, (iii) 60-liter can tests revealed slightly lower maximum pressure and higher time to maximum pressure for recalled inflators compared to newly manufactured inflators, (iv) the disassembly of recalled inflators commonly revealed corrosion within the inflator assembly, primarily on the locator disk, (v) leak tests performed on fifty recalled inflators found three with a high leak rate, (vi) for inflators manufactured between 2001 and 2004, measurements did not show a trend between the age of the inflator and the maximum internal pressure measured, and (vii) the crush force of recalled propellant was reduced by about 25 percent below that of new propellant due to the influence of increased temperature and/or humidity.

Fraunhofer's findings did not dispute Takata's hypothesis that ruptures derived from overpressure in the inflator chamber caused by weakened batwing propellant wafers. Based on Fraunhofer's findings relative to the chemical stability of the propellant and its ballistic performance, Takata believed that manufacturing problems may have contributed to the root cause of the weakened batwing propellant wafers. Fraunhofer's initial analyses were consistent with Takata's hypothesis that press problems could potentially result in mechanically weak batwing propellant wafers whose crush strength decreases over time.

XI. August 2011 to December 2011: PSDI Recalls Expanded to Include All Inflators Manufactured During the Stokes Era

A. *August 2011 to September 2011: Takata learns of a PSDI rupture outside of prior recall ranges and develops the "mixed propellant lot" hypothesis*

On August 1, 2011, a PSDI inflator ruptured in a vehicle in Pompano Beach, Florida ("Case 18"). Takata's records indicated that the Case 18 inflator was manufactured using propellant from the Gladiator 1 press. Notably, only the secondary chamber of the inflator ruptured (*see* explanation and images, below).



At that time, Takata's existing root-cause hypothesis was that the event ruptures were a result of low-density batwing wafers produced on the Stokes press (due to lack of quality control functions and low compaction load) or the

Gladiator 2 press (which had a series of maintenance issues). The ruptured inflator in Case 18 was not accounted for in Takata's root-cause hypothesis and, accordingly, had not been the subject of a recall.

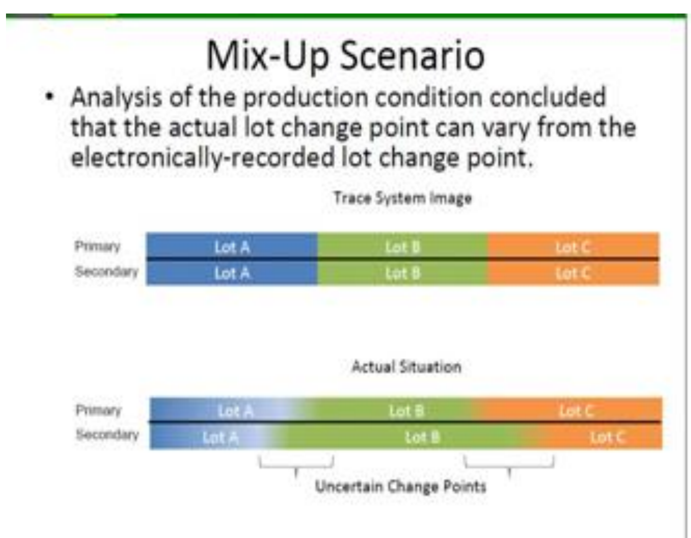
On September 14, 2011, the vehicle manufacturer and Takata met to discuss Case 18. Takata acknowledged that its trace data showed the Case 18 propellant was pressed on the Gladiator 1 press. Takata suggested to the vehicle manufacturer, however, that the Case 18 propellant may actually have come from a Stokes press but was mislabeled as Gladiator propellant due to recordkeeping mistakes made during the period when the Gladiator 1 and Stokes presses were used back to back. Takata reached this conclusion by analyzing its propellant production and shipping records and finding that the propellant used in the Case 18 inflator was wrongly attributed to a propellant lot manufactured on the Gladiator 1 press instead of the Stokes press.

At a September 14, 2011 meeting with the vehicle manufacturer, Takata further concluded that, based on the periods when the different presses were used, the mislabeling of inflator lots was not a widespread issue. Takata assured the vehicle manufacturer that it would, before the next meeting, (i) further explore the possibility of "mixed propellants" from the transition phase between Gladiator 1 and Stokes to see if any other propellant was mislabeled, and (ii) establish a plan to address the "worst case scenario," in which 230,000 inflators could be subject to recall.

B. *September 2011 to October 2011: Follow-up research confirms Takata's initial conclusion that the Case 18 PSDI inflator contained some Stokes-pressed propellant*

At an October 13, 2012 follow-up meeting with the vehicle manufacturer, Takata explained how it kept manufacturing records during propellant and inflator production processes. Takata kept a trace record of all inflators, which records the inflator number and the date and time the propellant was added, and identifies the propellant by lot number. Takata used these trace records to help the vehicle manufacturer identify what vehicles should be subject to a recall.

At the meeting, Takata explained the concept of the lot change point, which, in theory, is the moment inflator manufacturing switches from one lot of propellant to another. In Takata's tracing system, these points appear to be precise and singular. However, in practice, the change points are somewhat imprecise and are not uniform (*see* below).



One of the potential causes suggested by Takata for the imprecise lot change points involved the fact that the trace system reflects only the propellant in the PSDI's primary chamber, which may have differed from the propellant in the

PSDI's secondary chamber. During the manufacturing process, the primary chamber received propellant from the primary propellant supply line and the secondary chamber received propellant from the secondary propellant supply line. Due to the primary line's using propellant faster than the secondary line, the primary and secondary supplies did not always exhaust at the same moment. However, Takata's electronic trace system only recorded the propellant lot changes to the primary supply line, while the lot changes to the secondary supply line were recorded manually on line sheets. Thus, it was possible that an electronic trace record would indicate that the inflator contained Gladiator propellant, when Stokes propellant was in the secondary chamber.

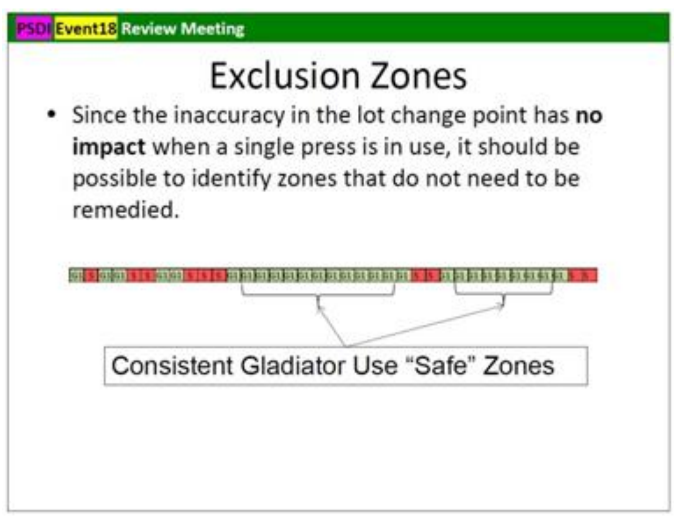
With respect to the Case 18 event, Takata concluded that the trace history for the inflator misidentified the propellant as being from a Gladiator press lot (Lot 6156), when it actually contained propellant from a Stokes press lot (Lot 6223). Takata's conclusion was supported by the manually completed line sheet paperwork signed by the manufacturing supervisor. Takata also learned that after the change to the Stokes propellant, Takata produced 26 inflators before producing the inflator in Case 18. Takata reasoned that the inflator manufacturing staff waited some period of time after updating the paper record of the lot change before updating the electronic record. As such, the electronic record did not accurately capture the time of the change point and inaccurately recorded the propellant in the Case 18 inflator as having come from the Gladiator press. At a minimum, the line sheet paperwork confirmed that the secondary chamber supply line was using Stokes propellant during the time the Case 18 inflator was produced.

C. *December 2011: Takata recommends, and the vehicle manufacturer initiates, a recall covering all inflators with propellant produced while the Stokes press was in use*

When Takata and the vehicle manufacturer met on December 1, 2011, Takata reiterated to the manufacturer that it believed—based on the line sheet and manufacturing records—that the Stokes-pressed propellant was put into the secondary chamber of the Case 18 inflator. This explanation accounted for a key feature of the Case 18 rupture, *i.e.*, the fact that only the secondary chamber ruptured. Further, the explanation was consistent with Takata's then operative root cause hypothesis, *i.e.*, that the lack of density caused by the Stokes press was the root cause of the field ruptures.

The Case 18 analysis indicated that it was not always possible to identify with certainty which inflators had Stokes-pressed propellant and which inflators had Gladiator-pressed propellant. Takata told the vehicle manufacturer that it tried to find specific areas with a situation comparable to Case 18, and while Takata found some areas of concern, it could not ensure propellant labeling with 100 percent certainty.

In Takata's view, the mislabeling issue that resulted in the Case 18 inflator's containing Stokes-pressed propellant when records said it contained Gladiator 1-pressed propellant was limited to instances when the Stokes and Gladiator 1 presses were used simultaneously or in short, back-to-back intervals. Accordingly, Takata reasoned that for certain intervals when the Stokes press was not in use ("exclusion" or "safe" zones), Takata could confirm that the inflators produced during those intervals did not have the Case 18 problem. Using electronic records, line sheets for the primary chamber supply, and line sheets for the secondary chamber supply, Takata identified and corroborated four "safe



zones."

With that information in hand, Takata and the vehicle manufacturer discussed another recall. There were two options: The vehicle manufacturer could expand the recalls to include all inflators produced while the Stokes press was active, or it could expand the recalls to include all inflators produced while the Stokes press was active except those inflators produced in one of the four safe zones. Ultimately, Takata recommended and the manufacturer executed a recall of all inflators produced during the Stokes era, including those made during the four safe zones.

On December 1, 2011, the vehicle manufacturer informed NHTSA that it would expand Recall No. 11V-260.[32] The vehicle manufacturer stated that it had learned of a rupture that was "outside of the VIN range of previous recalls, and the inflator module installed in the vehicle was outside of the suspect range previously identified by the supplier." In reaching the decision to expand the recall to all "potentially affected vehicles," the vehicle manufacturer explained that its "supplier's manufacturing records for the period in which this recently ruptured inflator was manufactured revealed a small degree of uncertainty regarding which driver's airbag inflator modules may have been produced utilizing propellant from the suspect processing equipment."

XII. 2012 to 2013: Following the Early Recalls, Takata Continues Its Investigation into PSDI Ruptures

A. *December 2011 to January 2012: NHTSA requests a joint meeting with a vehicle manufacturer and Takata following the December 2011 recall*

On December 21, 2011, the chief of ODI's Recall Management Division contacted an employee at the vehicle manufacturer to request a meeting with the manufacturer and Takata to discuss the ongoing inflator recalls. Specifically, ODI requested timelines of the field occurrences, summaries of both companies' testing and analysis, summaries of both companies' understanding of those tests, and an explanation as to why the manufacturer and Takata were confident in these findings.

Takata and the vehicle manufacturer met to discuss the NHTSA request on January 6, 2012. They agreed to produce a detailed timeline reflecting their ongoing understanding of the field events and a summary of their analyses. In addition, the companies planned to offer an explanation of how their understanding of the root cause of the field events had changed over time. The vehicle manufacturer was to explain all customer communications regarding the recalls, and Takata was to provide a description of all records and process controls for the inflator manufacturing process.

On January 10, 2012, ODI sent Takata's outside counsel and the vehicle manufacturer a non-exhaustive list of questions for the meeting, which was scheduled for January 26, 2012. Generally, the questions related to: (i) the design and intended use of the inflators; (ii) the companies' ongoing root cause analyses; (iii) the tests and analyses used to support those root cause hypotheses; (iv) any possible root cause explanations that were prematurely ruled out; (v) the potential scope of an expanded recall to include other affected inflators, including those sold to other vehicle manufacturers; and (vi) upstream supply issues that may have impacted the propellants or the inflators.

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[32] The vehicle manufacturer had originally informed NHTSA that it would conduct Recall No. 11V-260 on April 27, 2011. That recall was initiated to replace 2,430 inflators that had been installed as service parts or remedy parts in an earlier recall. However, owners of over 800,000 vehicles were notified because the vehicle manufacturer was concerned that it might not be able to identify precisely the vehicles in which those parts were installed.

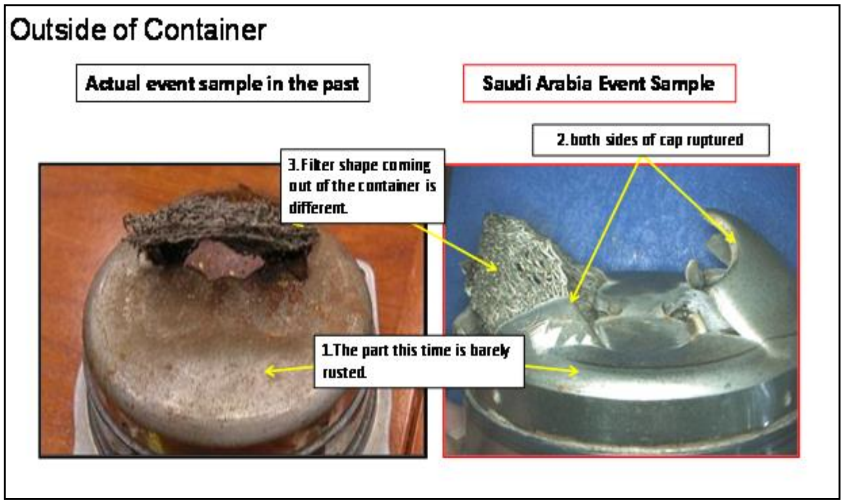
The vehicle manufacturer's and Takata's joint presentation contained references to presentations prepared for meetings between Takata and the vehicle manufacturer between 2007 and 2011. It appears that the vehicle manufacturer and Takata discussed the analyses behind each of the four PSDI recalls to date, detailing the rationale behind each recall. In relevant part, Takata disclosed that its records indicated the Case 18 inflator was produced with Gladiator-pressed propellant, which, to that point in time, had not been involved in any recalls. Takata stated it discussed its findings with the vehicle manufacturer, and ultimately, the two agreed that the situation required the recall of all inflators produced with propellant from the Stokes era. There apparently was no follow-up or formal action from NHTSA following the meeting.

Among the presentations from 2007 to 2011 that were referenced in the NHTSA presentation was a presentation given by Takata to the vehicle manufacturer on July 31, 2007. The July 31, 2007 presentation, which reviewed Takata's plan at the outset of the root cause investigation in response to ruptures that occurred in the field in 2007, contained a slide indicating that Takata found in its review of the DV and PV reports for the PSDI that the June 23, 2000 PV report (AJO1034) had "[n]o issues noted." While it is technically true that the PV report from TKC did not note any issues during testing, as discussed above in section V.D, that report contained selective, incomplete, or inaccurate data. There is no indication that either the 2000 PV or the July 31, 2007 presentation was discussed at the NHTSA meeting, and a U.S. engineer in the inflator production group, who attended the meeting for Takata, does not recall that they were discussed. The engineer also believes that the NHTSA materials were put together to provide NHTSA with the history of Takata's and the vehicle manufacturer's root cause investigation.

B. *March 2012 to April 2012: PSDI rupture with Gladiator 3 propellant cannot be explained by the Stokes low-compaction hypothesis*

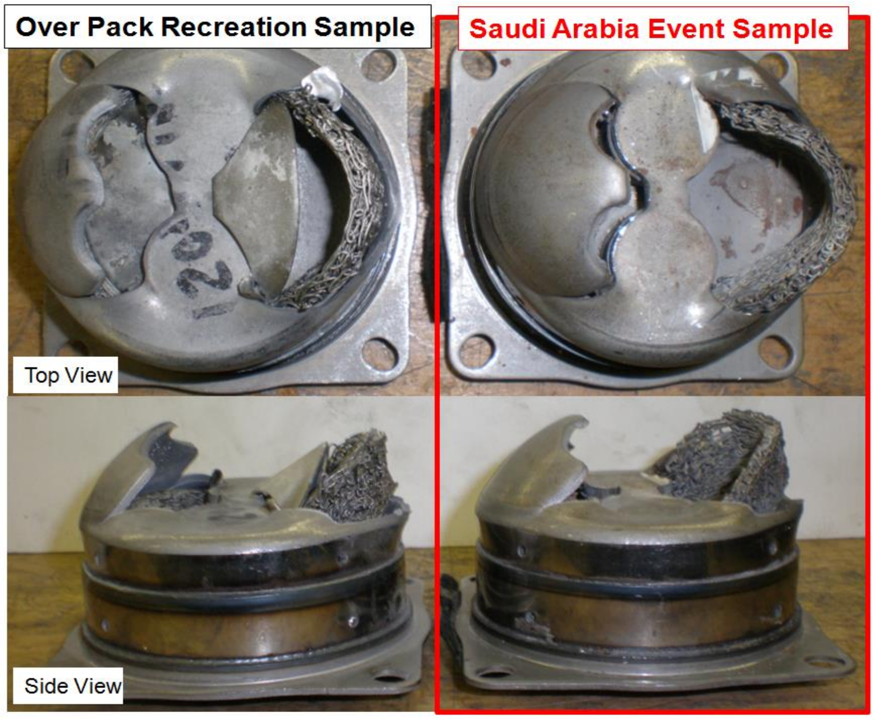
On February 20, 2012, a rupture event occurred in Saudi Arabia (the "Saudi Arabia event") involving a PSDI inflator manufactured in June 2003 with propellant pressed that same month on the Gladiator 3 press. Both the date of manufacture and the fact that the propellant was pressed on the Gladiator 3 press meant that this event was outside the previous recall range for PSDI inflators and thus challenged the prevailing PSDI root cause hypothesis centered on Stokes-pressed propellant. Takata immediately launched an investigation to determine the cause of the Saudi Arabia event.

In a meeting with the vehicle manufacturer in April 2012, Takata presented the results of its initial analysis of the Saudi Arabia event sample and its manufacturing inspection records. Takata underscored that there were several differences between the appearance of the Saudi Arabia event and a sample from a past PSDI event, including a lack of rust, a rupture of both sides of the inflator cap, and a difference in the appearance of the exposed filter (pictured below).



Through inspection of the Saudi Arabia event inflator, Takata found no deficiencies in assembly, no deformation on the booster cap, and no ruptures on crimps or welding. Takata thus ruled out as root causes (i) an insufficiently strong inflator housing, (ii) an overly aggressive ignition, and (iii) an insufficient gas outlet area. Through manufacturing records for the event inflator, Takata also confirmed that the press compaction load, density, moisture level, and propellant chemistry met specification.

During the April 2012 meeting, Takata presented a hypothesis that the rupture resulted from a propellant overload. Takata hypothesized that, in the event an extra batwing wafer (five as opposed to four) was inserted into the disk press, the overpack would cause the propellant to crush and break. This breakage would increase the surface area of the propellant and the eventual burn rate, possibly leading to excessive internal pressure and rupture. While the propellant manufacturing line had a batwing height check to make sure extra propellant was not loaded during the time the event inflator was manufactured, Takata surmised that the height check might not catch the overpack when a batwing was broken. Takata tested its hypothesis by overpacking a secondary chamber of a sample PSDI inflator with an extra batwing and then deploying the inflator. The result was similar to that seen in the Saudi Arabia event (*see* photos, below). Takata concluded that the overpack hypothesis should be further analyzed. Takata also determined that the effect of Saudi Arabia's extremely hot environment warranted additional consideration and proposed testing the hypothesis by conducting heat cycle aging tests for both the propellant and the inflator.



C. *April 2012 to August 2012: Further investigation into Saudi Arabia event and PSDI testing confirm "overpack" anomaly*

1. *June 2012: Takata's analysis of Gladiator 3 field returns shows no abnormalities or potential for rupture*

After learning of the Saudi Arabia event, Takata collected inflator samples from healthy vehicles in Saudi Arabia and Thailand, as well as recalled inflators from Israel, to examine the effects of hot climates on density, moisture, chemical degradation, and internal inflator pressure. In addition, Takata also analyzed nearly 500 field return PSDI inflators with Gladiator 3 propellant—the same propellant at issue with the Saudi Arabia event—from various regions in the United States. By looking at inflators from different regions in the United States, Takata sought to understand further whether internal pressure, propellant density, propellant moisture, or chemical stability differed by region.

Takata presented its findings to the vehicle manufacturer in early June 2012, and reported that none of the field return samples contained excessive moisture (ruling out degradation by moisture) or revealed chemical degradation suggesting destabilized ammonium nitrate. None of the Gladiator 3 field returns (from any country) showed abnormal internal pressure or a density level that could cause rupture. Further, the analysis of those inflators with Gladiator 3-pressed propellant recovered from different regions of the United States did not confirm any abnormalities, let alone abnormalities based on region. Abnormal pressure readings and low density propellant batwings were found in field returns from Israel, some of which caused ruptures when deployed. However, those ruptured inflators contained propellant pressed by the Stokes 340 or Gladiator 1 press, which were within previous recall ranges, and thus did not explain the Saudi Arabia event.

2. *April 2012 to August 2012: Takata confirms the overpack hypothesis*

By August 2012, continued analysis of field return samples had demonstrated that for inflators put through extreme heat testing, density loss did not occur, phase change was not observed, and output pressure was regular. Thus, Takata's analysis revealed it was unlikely that the effect of a high-heat environment was the cause of the Saudi Arabia event, essentially eliminating that root cause possibility.

Takata had continued to investigate the hypothesis that excessive propellant or an overpacking had caused the Saudi Arabia event. In testing the effects of excessive propellant upon deployment, Takata found that: (i) the inclusion of one extra batwing in the primary chamber resulted in no ruptures; (ii) the inclusion of one extra batwing in the secondary chamber resulted in a rupture 88 percent of the time (22 out of 25 tests); and (iii) the inclusion of two extra batwings in either the primary or the secondary chamber resulted in a rupture 100 percent of the time (5 out of 5 times tested). Further, Takata's testing appeared to show the ruptures with excessive propellant proceeded differently, with more pressurization, than those occurring due to low-density propellant.

Takata reported to NHTSA that it believed the Saudi Arabia event was due to overpacking. As of early August 2012, Takata had put together a preliminary frequency analysis to estimate a possible number of overpacking-related events. The analysis indicated only one overpack (in a primary chamber with one extra batwing) had been found in the inspection (by dissection or X-ray) of 25,000 inflators. From this data and the belief that at most three field ruptures were due to overpacking (Saudi Arabia, Switzerland in 2003 and possibly Event 0 in 2004), Takata estimated an upper bound probability estimate of 0.6 overpacking events to occur in the future given the remaining vehicle population. Takata concluded that the anomalous nature of the Saudi Arabia event did not warrant a broader recall.

D. *August 2010 to March 2013: Independent experts from Penn State analyze PSDI failures and propose a "dynamic burning" theory*

In the summer and fall of 2010, Takata and a vehicle manufacturer commissioned experts from Berkeley and Penn State University ("PSU") to provide an independent examination of the PSDI ruptures. The PSU team reviewed Takata's prior investigation and identified "certain undesirable combustion behavior and 2004 propellant-related factors" that warranted further analysis. PSU analyzed recovered PSDI inflators and newly produced PSDI inflators, as well as PSDI inflators from various geographical regions in an effort to identify any regional differences.

1. *PSU's March 2012 interim report confirmed much of Takata's prior testing and analysis but identified a "dynamic burning effect" of the 2004 propellant as a potential root cause*

On March 9, 2012, the PSU research team provided its first report, which had several findings. First, PSU confirmed that batwings returned from the southern region of the United States ignite with greater pressure than those from other regions and "are capable of producing enough internal pressure to rupture a PSDI housing." Second, PSU reported that its data on batwing burn rates "match[ed] Takata's previously recorded information closely." Third, PSU reported that during the ballistics testing of 44 inflators (30 new, 14 recovered), four ruptures occurred—all with recovered inflators and only with recalled propellant lots that were already known to exhibit anomalous behavior, which was consistent with Takata's prior testing and root-cause hypothesis.

Finally, PSU proposed a "dynamic burning" theory. Under this theory, the burning rate of a solid propellant can increase abruptly—and thus depart from the "steady-state" value—if the chamber pressure changes rapidly. PSU theorized that if such dynamic burning of the propellant occurs, an accelerated gas production rate could result in over-pressurization.

2. *After further review, PSU agreed that dynamic burning alone could not be responsible for the PSDI ruptures*

On May 24, 2012, the vehicle manufacturer informed Takata that the PSU expert, a long-time proponent of the dynamic burning theory, confirmed that he had some concern about the dynamic burning behavior of the 2004 propellant. The vehicle manufacturer sent Takata a series of questions about the propellant and stressed the seriousness of the situation. Takata responded that the concerns would be addressed at an upcoming June 2012 meeting.

On June 7, 2012, a U.S. engineer expressed his doubts about the dynamic burning theory's application to the 2004 propellant. The engineer highlighted internal inconsistencies in the PSU data, variations that were not representative of burn rates inside actual inflators, and implausible results. He also explained that there was little connection between PSU's dynamic burning rate measurements and the known performance characteristics of the 2004 propellant in the field. The engineer reiterated these issues to the vehicle manufacturer in July 2012 by critiquing the dynamic burning rate theory and questioning whether the PSU expert had the proper focus in his analysis.

Subsequently, the PSU expert updated his dynamic burning theory in a second interim report to suggest that a combination of dynamic burning behavior and enhanced surface area (*e.g.*, from cracked or broken batwings, batwings with low density or increased porosity, etc.) could "partially explain chamber over-pressurization phenomenon" and related rupture events. Further, in a June 28, 2012 meeting with Takata and the vehicle manufacturer, the PSU team concluded that "[b]ased on observation of current . . . data, we can conclude that a dynamic burning rate enhancement, in and of itself, is not sufficient to initiate the ED [energetic disassembly, *i.e.*, rupture] process." Rather, "[t]he ED process is likely caused by a combination of factors, not one single cause."

3. *November 2012: PSU's draft final report eliminated initial low density of batwings as a root cause and continued to identify "dynamic burning" as a contributing factor*

In a draft final report dated November 16, 2012, the PSU team presented its findings. First, as had been previewed for Takata and consistent with Takata's prior findings, the report concluded that the event ruptures were "definitely associated with overpressure rather than a structural flaw." As previously reported, PSU's test-firing of 30 recovered PSDI inflators had resulted in four ruptures (none for new production inflators) and all failures occurred with propellant lots that had been known to exhibit "anomalous behavior."

The PSU team's second major finding, however, was that "anomalous combustion behavior . . . is *not* correlated with reduced batwing sample density. Therefore, the observed ED behavior in PSDIs may not be associated with initial low-density pressing." This conclusion was in contrast to Takata's existing root cause PSDI hypothesis.

Further, as a result of focusing on over-pressurization (which Takata generally agreed with) while eliminating low-density batwings as a root cause, PSU proposed two new factors as contributing to rupture events. First, PSU concluded (as had earlier Takata analyses) that the AN phase stabilization for the propellant is effective assuming thermal cycling in the interior of the vehicle does not exceed 110ºC. However, PSU surmised that the "[m]aximum temperature encountered during thermal cycling in the vehicle may be higher than currently expected" and, at temperatures above ~115ºC, "the phase-stabilization of the ammonium-nitrate based oxidizer is no longer effective, which could allow changes in microstructure and burning behavior of the main PSAN oxidizer."

Based on data from four (out of at least 23) tests the PSU team conducted in an "O-frame chamber," the report concluded that a "[d]ynamic burning effect has been observed for 2004 Propellant under rapid pressurization conditions." This dynamic burning effect also is referred to as a "runaway burn" because an "[e]nhanced burning rate over the steady-state value could lead to a runaway situation, resulting in chamber over-pressurization." The PSU expert further suggested that the "existence of micropores and cracks can allow hot combustion product gas to penetrate more deeply into the pressed propellant sample for generating the preheating effect." According to PSU, this "preheating effect" can, in turn, "manifest itself as an enhanced dynamic burning effect." In other words, the PSU expert suggested that increasing pressure could lead to faster than expected burning rates, higher than expected temperatures, and even more rapid over-pressurization, resulting in an inflator rupture.

4. *November 2012: Takata disagrees with PSU's conclusions regarding low-density propellant and dynamic burning*

Takata's U.S. engineer disagreed with PSU's conclusion eliminating the initial low density of batwings as a root cause. He believed that PSU's conclusion was based on unfounded reliance on using helium pycnometer data to determine density, a method that had since been discredited. He explained that gas pycnometer readings were notoriously problematic in porous samples and were not valid because they tended to give the density of the base material, not the "bulk density." To get the bulk density, the surfaces of the propellant needed to be sealed against helium intrusion, which was not done when this method was used by PSU and measurements taken. The engineer concluded that the pycnometer readings would be accurate for measuring the volume of the 2004 propellant, but would be inaccurate for measuring density.

The engineer also disagreed with PSU's conclusion regarding the dynamic burning of the 2004 propellant. It was his view that no connection had been demonstrated between the dynamic burning rate measurements in the PSU O-frame device and the performance of 2004 propellant in any inflator. In fact, it could have been conclusively demonstrated that the proposed dynamic burning rate behavior as described by the PSU equation and coefficients could not exist in any of the inflator devices studied. The engineer also believed that the PSU measurements were taken on virgin, normal density propellant, which had no history of issues. He observed that PSU itself noted no issues with virgin normal propellant in any of its tests except their O-frame tests, which were conducted in an artificial, forced over-pressurization environment that did not mimic inflators.

Finally, the engineer believed that PSU's testing subjected the face of the 2004 propellant to temperatures far hotter than that at which the 2004 propellant actually burns when ignited in an inflator. This error may have caused "thermal feedback," resulting in burn rates not capable in an inflator.

In mid-November, the engineer's review of PSU's tests on dynamic burning apparently had convinced the vehicle manufacturer that PSU's analysis was not supported by the data.

5. *December 2012: PSU agrees that its density calculations were inaccurate, but maintains that low-density wafers can contribute to dynamic burning of the 2004 propellant*

In a December 18, 2012 response to the Takata engineer's analysis of the report, PSU agreed with the engineer's assessment of the inapplicability of helium pycnometry to measure propellant density. PSU therefore agreed to remove statements from the report comparing "known good" and "known bad" recovered sample density, and to revise its "previous conclusions based on this information that imply lack of relationship between the propellant sample density and observed combustion behavior." PSU also noted that "the relationship between density and combustion behavior is clearer to us, without contradictory data."

Rather than modifying its "dynamic burning" hypothesis, however, PSU proposed that lower density propellant may have a contributory effect on the dynamic burning rate of the 2004 propellant.

On January 23, 2013, the Takata engineer summarized the status of the PSU investigation. He noted that PSU had backed off all conclusions that the event ruptures were not correlated with low-density-pressed batwing wafers. The engineer indicated that he planned to meet with the PSU team to discuss further the dynamic burning theory. He stressed that the vehicle manufacturer had requested that additional dynamic burning testing be done and that Takata should continue to work with the PSU team.

6. *January to March 2013: Takata engineers and independent experts identify flaws in PSU's dynamic burning tests and data*

At the request of Takata, Fraunhofer reviewed the PSU materials and agreed with the Takata engineer regarding flaws in the PSU test method and lack of support for PSU's conclusions based on the data. Takata also asked an aerospace engineering expert from Georgia Tech to review PSU's testing, interim reports, and draft final report. On January 8, 2013, the Georgia Tech expert provided a brief report with two overall conclusions. First, he found that PSU's conclusion that a dynamic burning characteristic of the 2004 propellant is a cause of the over-pressurization events was unfounded for several reasons. Second, he agreed with the U.S. engineer's analysis and critiques because they were self-consistent and supported by experimental data, including first-order interior ballistics analysis that yielded reasonable engineering results. In summary, he found it unwise to preclude such important phenomena as burning surface variations and ensuing burning rate enhancement, and then draw conclusions, as PSU did, based on an isolated phenomenon (*i.e.*, dynamic burning) which may not occur in reality.

In March 2013, the U.S. engineer observed that out of at least 23 tests used by PSU to support its dynamic burning theory, data from only four tests were included in PSU's report. He further noted that some of the omitted data did not fit PSU's analysis. On March 13, 2013, the engineer met with the PSU team to discuss the PSU tests, underlying data, and the engineer's critiques. Essentially, the PSU team and the engineer did not agree on the results. As a result, the Takata engineer recommended: (i) performing additional testing at the PSU facility to mimic more closely the actual use scenario for ignition time, pressure, and other factors relevant to the 2004 propellant's operation in the PSDI inflator, and (ii) seeking the opinion of an independent party as to the validity of the parties' respective conclusions.

7. *March 2013: Despite critiques and continued discussion, PSU's revised final report maintained that dynamic burning, combined with low density and thermal cycling above ~115ºC, may contribute to the ruptures*

Notwithstanding these discussions, PSU's revised March 29, 2013 "Final Report on Evaluation of Combustion Performance of an Airbag" included the two previously identified factors that "may contribute to ED of PSDIs in the field": (i) maximum temperature encountered during thermal cycling in the vehicle that may be above ~115ºC resulting in the de-stabilization of the PSAN-based 2004 propellant, and (ii) dynamic burning effect. PSU also now incorporated low-density propellant as a third contributory cause, concluding that low-density propellant had "exhibited enhanced burning rates at high pressures . . . that could contribute significantly to the ED process when the propellant samples in certain PSDIs were not pressed to the suitable bulk density." Finally, PSU concluded that the combination of low-density 2004 propellant and dynamic burning effect "could have a combined effect to further enhance the probability of ED."

8. *November 2013 to November 2014: Additional follow-up with PSU yields no data*

On November 20, 2013, Takata entered into a new contract with PSU for follow-up testing and analysis regarding the possibility of a dynamic burning effect. The contract called for four discrete tasks to be completed between December 1, 2013 and September 30, 2014. The first task was to review all of the underlying data acquired in the original study. This task required PSU to transmit all data from tests to Takata regardless of the perceived utility of the test. The data was then to be reviewed by Takata's U.S. engineer and discussed with PSU in an effort to develop a consensus conclusion where possible. Tasks two, three, and four entailed new testing of inflators with modifications to the O-frame chamber created by PSU for testing. The contract also required the development of different ignition characteristics that would better approximate the actual ignition characteristics of Takata's inflators.

Nine months into the new contract, after a series of delays, PSU completed the first part of task one, which involved collecting, formatting, and transmitting the underlying data from its initial testing. The task-one report, provided by PSU to Takata on September 9, 2014, concluded that PSU's initial finding of a dynamic burning rate remained the same from the review of the whole test series.

On November 4, 2014, four days after the end of the contract period, the U.S. engineer informed PSU that continuing the project would be of no value, as the individuals at the vehicle manufacturer who were initially interested in the testing were no longer interested because the progression of the field issue strongly supported a conclusion of environmentally induced degradation—not a fundamental dynamic rate enhancement of virgin material as PSU proposed. The engineer concluded that since the contract period had ended, the project was finished and the dynamic burning rate effort was closed.

E. *April 2012 to October 2012: Analysis of batwing wafers by MIT and Cambridge University finds link between press compaction force and propellant pore size*

In April 2012, Takata engaged experts at MIT and Cambridge University to use imaging techniques called MicroCT, a form of digital X-ray imaging, and terahertz pulse spectroscopy, which uses terahertz radiation for imaging, to analyze the internal porosity of batwing wafers.

MIT and Cambridge analyzed the porosity of four samples: (i) one newly made, high-density/high compaction force sample, (ii) one newly made, low-density/low compaction force sample, (iii) one high-density field-returned inflator, and (iv) one low-density field-returned inflator. The final report, which was completed by October 2012, concluded that the newly made, low-density propellant had far greater porosity, and far larger pores, than the newly made, high-density propellant. This increase in large pore size leads to increased pore connectivity, which, the report hypothesized, may be responsible for the faster ignition of batwings. The report also concluded that the low-density field return has lower porosity than the low-density newly produced propellant, which suggested a higher starting density in the field-returned sample.

While the final report did not offer definitive conclusions that relate to the root cause of the ruptures, it did suggest that newly produced wafers with low compaction force were especially problematic due to their large, interconnected pores. Conversely, wafers that were produced at high densities but became low density through field aging were seen as less problematic because they did not exhibit the same large, interconnected pores.

F. *April 2012 to November 2012: Hermeticity testing by Fraunhofer reveals PSDI manufacturing defects and moisture intrusion*

1. *Spring 2012 to June 2012: Fraunhofer tests PSDI-X inflators and finds moisture intrusion sufficiently compensated for by 13X desiccant*

In addition to other independent experts, Takata engaged Fraunhofer to investigate the PSDI ruptures and perform a root cause analysis. During the spring of 2012, Fraunhofer tested two types of inert PSDI-X inflators to isolate potential moisture leaks through (i) the inflator's tape seal over the gas nozzles, and (ii) the inflator's igniter assembly. The inflators were filled with helium gas to measure leak rates and 13X desiccant to capture any moisture that might enter the inflators during testing. After performing a series of USCAR tests, including a sequential test of humidity resistance, dynamic shock, and high heat and humidity, Fraunhofer's major findings were as follows:

- The helium leak rate measurements showed that the inflators built with only igniter assemblies had a higher average leak rate compared to the inflators built with only nozzles and tape seals.
- All inflators tested, however, remained in compliance with the USCAR helium leak rate specification.
- According to the mass gain of the 13X desiccant over the course of the tests, more moisture intruded into the inflators built with igniter assemblies when compared to the inflators built with nozzles and tape seals.

During these tests, an average of 0.3053 grams of 13X desiccant entered each test inflator (consistent with the minimum quantity of 13X to be included in each PSDI-X inflator assembled to specification). The mass of the 13X increased by 5.24 percent on average when the moisture gain results of the inflators with igniters and inflators with nozzles and tape seals were combined. Fraunhofer concluded that the 13X desiccant in the X-series inflators is sufficient to contain this amount of moisture intrusion. At ambient temperatures, 13X has a capacity to hold up to approximately 25 percent of its mass in moisture, according to data supplied by Takata.

However, Fraunhofer found that saturated 13X begins to release moisture when temperatures increase to 40ºC. At 80ºC, the moisture capacity of 13x decreases to 20 percent of its mass. At 107ºC, the moisture capacity of 13X decreases to 11 percent of its mass. As a result, Fraunhofer advised on the possible need to investigate the use of more desiccant and a different desiccant material that does not release moisture below 100ºC for the purpose of providing a more robust defense against moisture intrusion.

2. *April 2012 to July 2012: Fraunhofer dissects 60 PSDI inflators recalled from three climatic regions and discovers manufacturing defects that could promote moisture intrusion*

In April 2012, Fraunhofer hypothesized that moisture could be intruding into PSDI inflators due to cracks formed in the insulating glass of the igniter pins.[33] Fraunhofer requested 60 already-recalled PSDI inflators from three climates in the U.S. to test the hypothesis: (i) 20 from the Gulf states (high heat and high humidity); (ii) 20 from the Southwest

[33] PSDI inflators have two igniters—one for the booster propellant (3110) of the primary chamber and one for the booster propellant of the secondary chamber. The 3110 tablets, in turn, pressurize and ignite the main propellant batwings (2004/2004L) in the primary and/or secondary chambers in a chain reaction. Glass is used to provide the electrical insulation for the igniter pins. The glass also will provide a strong hermetic seal as long as it is not damaged.

(high heat and low humidity); and (iii) 20 from Great Lakes states (high humidity and low heat). Fraunhofer also planned additional tests to analyze BHT aging and BHT particle size in recalled batwings from event lots and non-event lots to determine whether rupture events are correlated with smaller BHT particle size during the early stages of production in 2000-2001.

When the 60 recalled PSDI inflators from three separate regions were sent to Fraunhofer to conduct leak path testing, in the course of extracting the igniters from the igniter assemblies, a series of unexpected problems were identified after the igniter housings were removed. These problems generally fell into six categories:

(1) Igniter assemblies that had a crack next to the O-ring, which can cause the metal assembly to pinch the O-ring;

(2) Abrasions down the inner edge of the booster tube port;

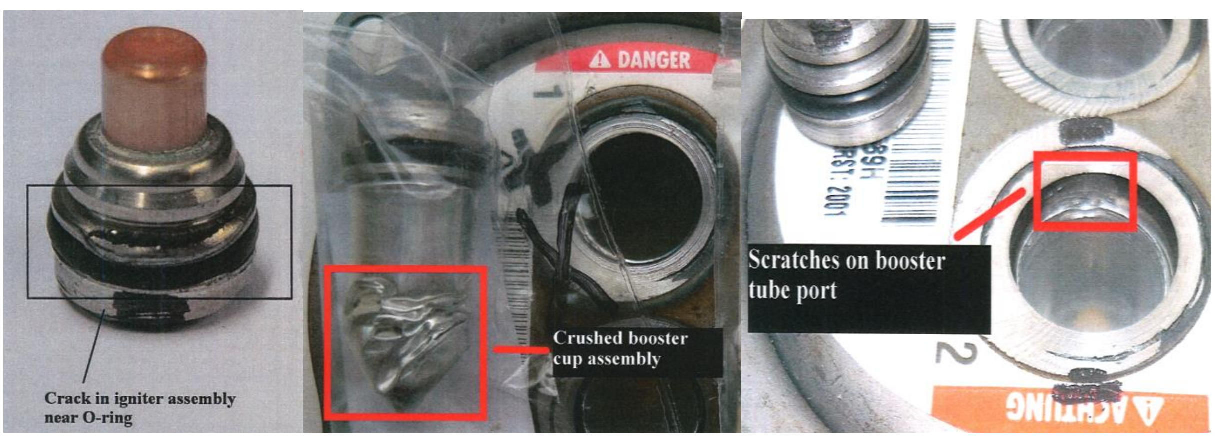
(3) Scratches on the booster tube port and dents next to the O-ring on the igniter assembly;

(4) A crushed booster cup assembly;

(5) Broken and cracked booster propellant tablets; and

(6) Dark discoloration of AI-1 tablets located at the bottom of the booster tubes.

In total, 18 of 60 PSDI inflators (30 percent) examined by Fraunhofer had suffered some physical damage (categories 1-4, above) during manufacturing, and 6 of 60 (10 percent) had severe damage.



Fraunhofer hypothesized that welding heat, along with other potential manufacturing processes, caused the imprecise fitting of the component parts and resulting damage. The cracks in the igniter assemblies, as well as the other abrasions and dents, could promote moisture intrusion, which could worsen over time. In addition, the crushed booster cup assembly caused broken 3110 tablets, which could make the booster propellant more energetic and could adversely affect ballistics during ignition. Because these inflators had been dissected, no ballistic tests could be performed to determine the possible effects upon the performance of these inflators.

3. *November 2012: Fraunhofer's final report confirms PSDI manufacturing issues and potentially significant moisture intrusion when subjected to military-grade environmental testing*

In a November 2012 report, Fraunhofer provided its findings regarding the following topics it had investigated to uncover the root cause of PSDI ruptures:

- BHT particle size[34] analysis of propellant from recalled event and non-event lots, including Gulf state climates (propellant properties like density, dimensions, and crystalline structure also were determined);
- Moisture intrusion testing of potential water migration through the igniters; and
- Examination of igniter and/or booster assembly defects in recalled inflators.

In total, 80 PSDI inflators were utilized—10 each of known event and non-event lots (for the BHT particle size analysis) and 60 from three different climate regions in the U.S. (Gulf states, Southwest, and Great Lakes for igniter moisture intrusion testing). During dissection of event and non-event lot inflators, some were found with "a lot of rust inside especially at the booster tubes." Some propellant also showed signs of decomposition from excess heat during welding.

Fraunhofer found that, because the particle size distribution curves of the event and non-event lots generally overlapped, no meaningful difference was detected and no correlation was found between propellant lots with known rupture events and smaller BHT particle size. Regarding other propellant properties, no meaningful difference was detected in batwing height (the maximum absolute deviation from the mean value was 7 percent) or crystalline structure. However, the batwing propellant from the primary as well as secondary chambers of two event-lot inflators demonstrated a 50 percent decrease in crush strength, a significant change that likely would impact ballistic performance. Nevertheless, due to the batwing shape, crush testing results were highly variable.

The 60 PSDI inflators recalled from different climate regions were dissected to extract the igniters. Each of the igniters was inspected against rough leaks by vacuum test and then placed as part of a test setup in a climate chamber. Once in the climate chamber, Fraunhofer subjected all of the igniter assemblies to a military moisture testing standard (MIL-STD-810F). By the end of the eighth 48-hour cycle of the MIL-STD-810F test, the recalled igniters had been exposed for 384 hours (16 days) to a relative humidity of 95 percent while cycling between 20ºC and 60ºC.

This military-grade test is more rigorous than the validation tests required of Takata by the vehicle manufacturers. For example, one Japanese vehicle manufacturer's validation test for humidity resistance places the inflator at 95 percent relative humidity for only 144 hours and at a constant temperature of 60ºC. The vehicle manufacturer does not require temperature cycling. The USCAR test is more rigorous than the vehicle manufacturer's test, but is still less rigorous than MIL-STD-810F insofar as it does not require as much cycling. The USCAR test holds the inflator for 192 hours at a relative humidity of 95 percent while cycling the inflator between 90ºC and -40ºC. Thus, the USCAR test is only half the duration of the MIL-STD-810F test. Furthermore, a helium leak test required by vehicle manufacturers to check for leaks would not be expected to detect the ability of moisture to diffuse through the nylon plastic igniters and O-ring material due to thermal cycling over time that creates negative internal pressure.[35]

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[34] In general, a smaller particle size results in a higher burn rate at the same pressure. A higher burn rate, in turn, leads to higher maximum pressure, which could exceed the burst pressure of the inflator and result in a rupture. The other ingredients of the 2004 propellant—ammonium nitrate, potassium nitrate, and strontium nitrate—are not relevant because they are water soluble and, therefore, are dissolved into the 2004 propellant mixture during the wet mixing process. Conversely, BHT is only sparingly soluble in water. As a result, only the BHT particle size distribution could influence burning behavior.

[35] Fraunhofer conducted later analysis and found that the test of humidity resistance with lower temperatures actually causes a "drying cycle" and does not replicate the high absolute humidity environments.

Fraunhofer also confirmed that it had identified two major manufacturing issues in the course of dissecting the PSDI inflators. First, Fraunhofer observed "squeezed" or crushed booster cups. Second, Fraunhofer observed damage at the igniter support and the igniter port in the inflator housing, including small scratches, breaking of igniter supports, metal denting at the ports and/or a bent rim below the O-ring. Fraunhofer believed that these "damages [sic] obviously arise from the insertion and crimping process of the igniter assemblies." Moreover, "a lot of rust was detected inside the inflators at the interfaces of propellant and steel." In total, as Fraunhofer had revealed in July 2012, 6 of 60 inflators (10 percent) suffered from "severe damage."

XIII. October 2011 to April 2013: Ruptures of Passenger Airbag Inflators, Additional Investigation, and Recall Efforts

A. *Further investigation of milled BHT, events in Japanese salvage yards, and the initial SPI passenger inflator recall*

As the driver inflator events began to occur and a root cause investigation was conducted, from 2007 to 2009, Takata recognized that the original PSAN passenger inflators, like the early PSDI driver inflators, contained milled BHT. As a precaution, even though there had as yet been no field events involving passenger inflators, Takata did a further review of inflator performance relating to milled BHT. Beginning in May 2009, after a vehicle manufacturer began reporting SPI anomalies in Japanese scrapyards, engineers at TKC and Takata again investigated issues related to milled BHT. In June 2010, Takata met with a vehicle manufacturer and presented an analysis of the SPI inflator events, noting that three ruptures occurred during disposal in Japanese junkyards. This presentation reflected three different possible factors as the root cause—(1) missing propellant retainer, (2) missing spring, and (3) missing propellant wafer—but did not address milled BHT. Following the rupture of a fourth SPI inflator in a Japanese salvage yard in June 2010, two Japanese vehicle manufacturers initiated recalls of certain vehicles equipped with SPI inflators with propellant from Gladiator 1 and 2 presses (start of production through November 10, 2000). The recall effort, supported by Takata, involved over 160,000 vehicles globally, but less than 100 in North America. As of that time, there had not been any reported SPI ruptures involving vehicles in operation.

In addition, beginning in the fall of 2010, a senior U.S. engineer and an engineer from TKC discussed the ability to rebuild PSPI inflators with milled BHT. This rebuild project included evaluating the history of milled BHT and the fact that samples of PSPI inflators (milled and unmilled) would be sent to Japan. Also in the fall and winter of 2010, Takata began to conduct further testing in China of SPIs and PSPIs related to issues connected to milled BHT. On January 10, 2011, engineers completed the build, and the inflators were sent to China. It is unclear what resulted from this effort.

B. *October 2011 to June 2012: Takata launches a new investigation after learning of passenger inflator ruptures in the field*

1. *October 2011 to November 2011: Takata learns of two passenger inflator ruptures and opens an investigation*

In October 2011, a vehicle manufacturer received a field report from Japan indicating that a vehicle involved in an accident had sustained thermal damage to the instrument panel after the front passenger airbag, which contained an SPI inflator, deployed. An initial inspection of the airbag found that upon deployment, the inflator had fractured near the gas ejection orifices located in the center portion of the inflator body. The SPI inflator had been manufactured in July 2001 and contained propellant pressed in July 2001. Thus, it was outside the range of the prior SPI recall.

Takata was notified by another vehicle manufacturer in November 2011 that a vehicle in Puerto Rico had experienced a rupture of both a driver inflator (PSDI) and passenger inflator (PSPI). The passenger inflator had been manufactured in June 2001 and contained propellant pressed in April 2001. Takata opened an investigation into the two passenger inflator rupture events.

The production records for the two passenger airbag modules showed that the inflators in each had been made with Gladiator 2-pressed propellant wafers. Takata conducted a preliminary fault tree analysis and pinpointed a number of areas for further investigation as possible root causes, including: (i) low density due to insufficient press force; (ii) low density due to high moisture rate; and (iii) increased propellant surface area due to deficient propellant or broken wafers. Takata's investigation of these hypotheses included examining parts from the Puerto Rico event, reviewing the Gladiator press maintenance history, and collecting and analyzing additional PSPI and SPI inflators.[36]

2. *November 2011 to June 2012: Further investigation into passenger inflator ruptures and Takata's inability to recreate the failures*

After launching its investigation into the passenger inflator ruptures, Takata met with the two vehicle manufacturers every few months to discuss the investigation. These meetings often consisted of Takata's proposing or eliminating possible hypotheses, the vehicle manufacturers' inquiring about specific manufacturing processes, and Takata's agreeing to run data to respond to the questions.

On April 23, 2012, Takata presented a vehicle manufacturer with its interim analysis on the passenger inflator rupture in Puerto Rico. Takata's re-creation testing showed that the rupture was due to high pressure in the primary chamber, rather than any failure in the inflator housing or excessive pressure in the secondary chamber. Takata stressed at the outset, however, that without the event inflator, no conclusions could be made about the root cause of the high pressure.

Because the event inflator was not recovered, Takata undertook a series of re-creation tests to try to simulate the failure mode seen in the event inflator, including moisture and aging effects and temperature cycling, overly aggressive propellant output due to damaged propellant, and bulkhead defects. The re-creation tests were unsuccessful in identifying the cause of the high-pressure failure mode observed. As a result, possible root causes that could not be ruled out included aggressive propellant resulting from poor properties or improper load, and the over-pressurization of the primary chamber due to aggressive ignition. Without additional samples for Takata to test for patterns, further clarification of the cause was unlikely. A complete moisture and cycling program was recommended, as well as the collection of healthy inflators from the field for testing and analysis.

Much of Takata's investigation into the PSPI and SPI ruptures centered on manufacturing changes and processes. As a follow-up from the April 2012 meeting, the vehicle manufacturer requested a detailed chronology of all the change points related to propellant and inflator manufacturing, which Takata completed and reviewed. In May and July 2012, the vehicle manufacturer conducted on-site manufacturing inspections of both the Monclova and Moses Lake facilities.

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[36] Around this time, Takata also investigated whether moisture might have leaked through the tape seal on an SPI inflator due to environmental exposure, since the SPI in question had malfunctioned following a typhoon. Takata conducted a series of tests to simulate the effect on a passenger inflator submerged as a result of a flood. None of the tested inflators showed evidence of water leakage or reflected the corrosion seen in the SPI event inflator.

Takata and the two vehicle manufacturers also collected healthy and recalled passenger inflators from the United States, Japan, the United Arab Emirates, and Saudi Arabia. The purpose was to dissect and deploy the inflators to verify wafer density, moisture content, any chemical change and interior pressure. From February to June 2012, Takata conducted replication tests on field inflators, but was unable to reproduce the problem.

C. *October 2012 to September 2013: The auto-reject hypothesis*

1. *Re-creation tests and identification of low press load as possible root cause*

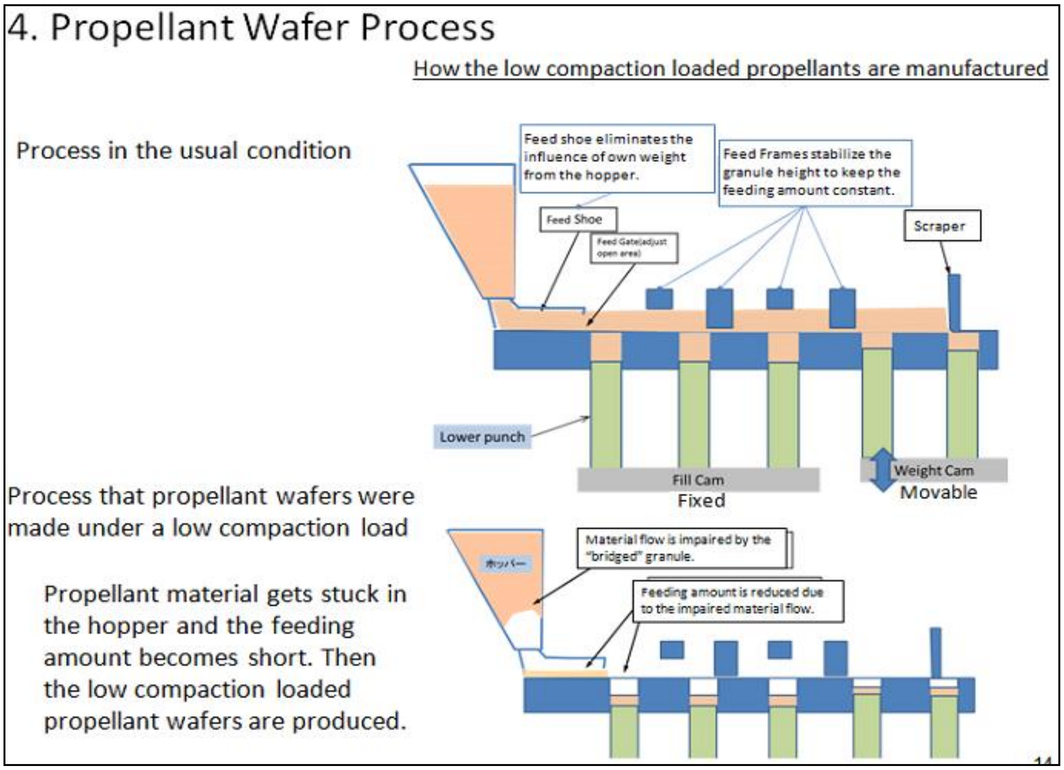
At an October 1, 2012 passenger inflator review meeting with one vehicle manufacturer, Takata shared its root cause hypothesis for the source of the ruptures and traced its investigation to date. Takata indicated that 12 passenger ruptures were known: three SPI events that were subject to prior recalls, the Puerto Rico and Japanese field incidents that had sparked the investigation, and seven incidents that occurred in Japanese scrap yards.

Takata's analysis consisted of a review of event inflators, re-creation testing, and data from testing of healthy inflators recovered from the field.[37] Through a series of fault tree analyses, Takata ruled out several potential root causes, including issues related to the strength of inflator housing, excessive loading of propellant, pulverization of ignition material, improper sealing, and excessive moisture content.

Takata also conducted a series of tests to investigate the possibility of low compaction load (or "press load") during the propellant production process. As Takata stressed in its prior investigations into PSDI ruptures, propellant density is a critical characteristic of its performance. Takata knew that inadequate compaction force could affect propellant density. Indeed, the governing root cause hypothesis at this time for the PSDI field events was that poor compaction force on the Stokes press resulted in low-density batwing wafers that ultimately could lead to excessive internal pressure and ruptures.

Takata explained how low compaction load propellant for PSPI and SPI inflators could have been manufactured. If an improper amount of propellant granules was loaded into the press, a "bridge" would be created that essentially clogged the flow of propellant and resulted in a decreased feed of propellant (*see* depiction, below). The compaction load during pressing varied based on the amount of propellant. Thus, the hypothesis was that decreased feed caused by the clog resulted in propellant lots with low compaction load.

[37] Takata focused on the nine event inflators that had been manufactured outside the previous SPI recall range.



Further, the analysis of healthy PSPI inflators from North America, Saudi Arabia, and United Arab Emirates showed that several units pressed in 2001—the same period as the event ruptures—had low density, and four of the low-density units showed unusual inner pressure during ballistic testing.[38] Takata hypothesized that these low-density/high-pressure units may have been caused by the low compaction load issue identified above.

2. *Takata identifies an issue with the auto-reject feature of Gladiator presses*

As Takata had outlined to the vehicle manufacturer during an earlier PSDI investigation, all models of the Gladiator press (G1, G2, and G3) were equipped from the outset with a load assurance system, which had a real-time load adjustment if the press force deviated from specification. The Gladiator presses also included an auto-reject ("AR") function, which (when enabled) measured the compaction force for each propellant wafer and rejected those wafers made with a force outside of the specification.

Through its review of the production history of the presses, however, Takata learned that from the start of their use in propellant production ("SOP"), the Gladiator 1 (SOP May 22, 2000) and Gladiator 2 (SOP September 1, 2000) had the AR function turned off as a default setting and the function had to be manually turned on. Records indicating whether the AR function was operational for a particular production lot were not kept until September 9, 2001.[39] The AR interlock feature, which precluded manual shut-off of AR functionality, was not added until sometime later in 2001.

[38] The analysis of 127 healthy SPI inflators from Japan manufactured in 2001-2002 identified no abnormalities and no parts that would cause potential ruptures.

[39] The Gladiator 3 press was introduced in September 2001 and had automatic auto-reject functionality locked in from the outset.

Takata explained that all of the PSPI and SPI ruptures had involved inflators with either Gladiator 1 or Gladiator 2 propellant pressed when AR bypass was possible. Takata hypothesized that those events could have been caused by the combination of the low-compaction problem described above (clogged propellant feed caused by a “bridge” leading to low compaction) and normal vehicle aging. Further, Takata’s healthy parts analysis showed a lower and more consistent range of chamber pressure after deployment for those inflators manufactured after the AR function was presumed to have been in place and recorded.

Takata recognized that it was important to determine precisely when the AR function was operational such that compaction force could be guaranteed. Takata told the vehicle manufacturer that further investigation was necessary to confirm that December 19, 2001 was when the AR function was “auto-locked,” as any determination for recall purposes would have to take into account AR functionality.

3. *November 2012 to April 2013: Confirming the low-compaction/auto-reject hypothesis*

To test its low-compaction hypothesis, Takata undertook replication tests to analyze changes in density based on different press loads and in combination with thermal cycling. When the PSPI/SPI wafer propellant was made with a press load of 35,000 lbs., testing demonstrated that irregular tank pressure could occur after only three thermal cycles and inflator rupture occurred after four cycles. No irregular output was observed over five thermal cycles where the propellant press load was 44,000 lbs. or higher. Thus, Takata’s testing seemed to confirm that irregular output and ruptures could occur where the compaction load was low.

Takata’s production records indicated that Gladiator 1 and 2 presses were still manufacturing a limited number of propellant lots without AR after December 19, 2001. Further, the supplier of the Gladiator press met with Takata and the vehicle manufacturer in February 2013 and stated they had no records to confirm that the programming change was made in December 2001 as Takata initially believed. The press supplier could only verify that the AR was locked on all three Gladiator presses as of September 12, 2002. Takata ultimately set September 12, 2002 as the outer point it recommended for the relevant passenger inflator recalls.

4. *September 2012 to Summer 2013: Takata learns of three more passenger inflator ruptures and hires BakerRisk to evaluate*

Between September and November 2012, Takata learned of three more passenger inflator ruptures occurring in the field. Two of the events occurred in Puerto Rico and one occurred in Maryland (with a vehicle that had been operated in Florida for eight years). All three vehicles had been equipped with PSPI-L inflators. The propellant involved in the events were pressed on the Gladiator 1 press between May 22 and July 27, 2002.

The three ruptures prompted concern because they were not explained by Takata’s then-existing hypothesis that the passenger inflator ruptures involved propellant produced with low compaction when AR was not operating. Production records eventually showed that AR was functioning for the propellant lots used in the three inflators, and thus these ruptures could not be explained by the low-compaction hypothesis.

Takata proposed that the three events were distinct from the other passenger inflator ruptures because the vehicles in question were known to have an airbag module circuitry issue in control systems manufactured by another supplier, which could cause inadvertent deployment of the airbag. The vehicle manufacturer ultimately issued a recall in January 2013 based on the circuitry issue.

Takata enlisted BakerRisk to conduct a series of tests on PSPI-L inflators from warm and humid climates. Takata sought to test the proposition that the three ruptures would not have occurred without improper electronic deployment by the control system, and thus that the root cause was not in fact propellant quality. The hypothesis behind the tests was that heat transfer from the resultant firing of one chamber altered the condition of the propellant in the remaining chamber such that it was made more energetic (the "heat soak hypothesis").

BakerRisk issued an interim report on March 14, 2013 and a final report on July 23, 2013, but the results were inconclusive. The testing was unsuccessful in recreating a rupture in 33 PSPI-L inflators obtained from Model Year 2003-2005 vehicles by using an improper firing sequence. BakerRisk's tests and analysis did confirm a significant preheating of one chamber by the misfiring of another chamber, but the results of the 33 tests were inconclusive as to whether the heat soak hypothesis could account for all three ruptures.[40]

The dissection of 19 PSPI inflators from high temperature and high humidity areas of Puerto Rico, Florida, Texas and Alabama, however, resulted in (i) evidence of moisture intrusion into the inflators (as well as external rust, severe on about 25 percent of the inflators) (*see* photos, below), and (ii) a scientific explanation for the possible ability of moisture to permeate through rubber and plastic materials in certain warm and humid climates (*see* section XIII.G).

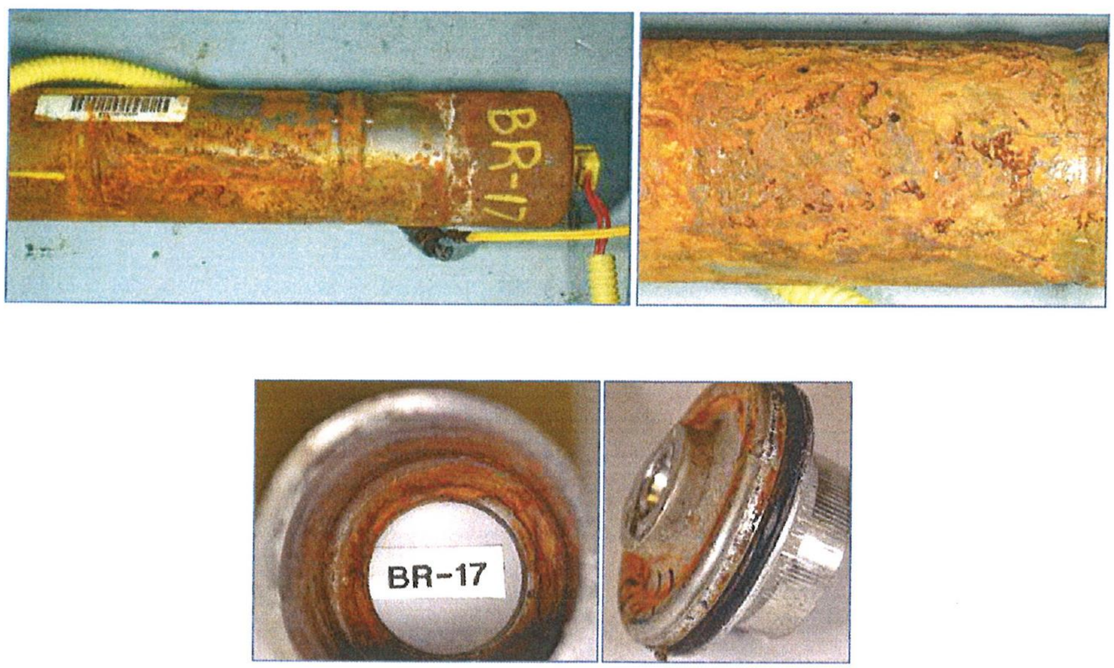


Figure 4. PSPI-L Disassembly showing Moisture Intrusion through the End Crimp

D. *October 2012 to April 2013: Weekend moisture hypothesis*

In addition to investigating the circuit issues and potential moisture intrusion post-production, by October 2012, Takata also investigated whether the three ruptures had propellant that might have been exposed to excessive moisture during inflator assembly in Monclova, Mexico.

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[40] Takata also enlisted Fraunhofer to conduct a root cause investigation of the passenger inflator events. Fraunhofer's testing involved (i) dissection of the SPI, PSPI, and PSPI-L inflators made between 2002 and 2004, and (ii) testing of inflators and propellant through accelerated aging.

Takata's records showed that two of the ruptured inflators were assembled on the same production line, 21 days apart, and both had been made on a Monday. The moisture hypothesis posited that when inflator production shutdown for the weekends or holidays at the Monclova plant, the operator may have improperly left unused propellant lots on the loading station instead of returning them to temperature-controlled storage. The dehumidifier in the loading station was then turned off during the production downtime, exposing those lots to higher moisture conditions than they otherwise would have been exposed to. Those propellant wafers—which could have absorbed moisture beyond permitted specification during the downtime—were then used once inflator production restarted after the weekend or holiday.

Based on a review of the manufacturing change point history, Takata believed that excessive moisture exposure was possible from the beginning of inflator assembly at Monclova in January 2001 until November 2002, when the facility assigned a specific worker to handle propellant and also made changes to control temperature throughout the plant.

Takata also conducted replication tests on passenger inflators to evaluate the effects of excessive propellant moisture combined with long-term environmental aging. Testing confirmed that excess moisture absorbed by the propellant could lead to the observed passenger events, with abnormal output and inflator ruptures occurring when the moisture level was 0.40 wt. percent or higher.

In March 2013, Takata opined to a vehicle manufacturer that moisture exposure in Monclova was a potential root cause of ruptures. Takata explained that all three of another vehicle manufacturer's inflators were assembled following at least a 24-hour period of downtime. Takata also noted that for the three event inflators, a less-experienced operator was working in the facility and excess propellant might have been treated improperly and absorbed moisture.

E. *March 2013: Disagreement regarding the auto-reject and weekend hypotheses*

Shortly after the March 2013 meeting with the vehicle manufacturer, a U.S. engineer in the inflator production group was asked to prepare for a similar meeting with another customer. After reviewing the relevant materials and records, the engineer met with a senior U.S. engineer, a U.S. engineer, and another Takata employee and explained that he believed that the auto-reject hypothesis was technically unsupportable and the weekend moisture hypothesis was inconsistent with production records. He challenged the auto-reject hypothesis because, he believed, it was disproved by the fact that almost none of the low-density field returns he examined were low weight. Thus, a normal weight wafer could pass the auto-reject function and still exhibit low density in the field. The engineer believed the weekend hypothesis was flawed because production records showed that the propellant lots used in the three field events were not introduced to the production line before a shutdown. As a result, the engineer believed that a recall based on the auto-reject and weekend hypotheses could result in a recall population that was both overinclusive of inflators that were not at risk, and underinclusive of inflators that were at risk. Because he disagreed with the explanation, the engineer declined to be part of its presentation to any customers.

Notwithstanding the engineer's disagreement with the auto-reject and weekend hypotheses, other engineers within Takata and TKC believed that these hypotheses were sound and reasonable based on their own contemporaneous analyses. Those engineers also believed that the scope of the recall based on these hypotheses was appropriate given the knowledge they had at the time.

F. *April 2013: Recalls of passenger inflators*

On April 11, 2013, Takata submitted a DIR to NHTSA outlining a potential defect it had identified in certain passenger inflators manufactured between April 13, 2000 and November 1, 2002. NHTSA identified this DIR as Recall No. 13E-017. Takata identified 12 passenger inflator incidents that it was aware of, including six in salvage years in Japan, four in the field in the U.S., and two in the field in Japan. Takata estimated at the time that the percentage of inflators potentially affected by the identified defect was "extremely low," "based on the very small number of field incidents that have occurred." Nonetheless, in view of the possibility that such a deployment could lead to an injury, Takata decided to declare that a defect related to motor vehicle safety may exist.

In describing the potential defect, Takata outlined its root cause hypotheses of (i) low-compaction load, and (ii) moisture exposure, and explained that, "[i]n both cases, the propellant could potentially deteriorate over time due to environmental factors, which could lead to over-aggressive combustion in the event of an air bag deployment. This could create excessive internal pressure within the inflator, and the body of the inflator could rupture."

Takata identified six vehicle manufacturers with vehicles potentially containing the defective passenger inflators. These vehicle manufacturers notified NHTSA that they had decided to conduct recalls based on Takata's decision.

G. *May 2013: BakerRisk's calculations demonstrate that moisture permeation into PSPI and PSPI-L inflators may be significant under high temperature and high humidity conditions over long periods of time*

According to a report prepared by BakerRisk in May 2013, moisture intrusion can occur in inflators "built as designed" due to a permeation process that can take place over time, in which water vapor permeates from a high humidity environment outside the inflator into the dry interior of the inflators, such as through the O-rings or igniters that seal the end of PSPI/PSPI-L inflators.

BakerRisk ran sample calculations designed to simulate permeation through a PSPI O-ring at high temperatures and humidity over 3,000 days (8 years), which showed that about 0.2 grams of moisture could be passed into the inflator. Because a PSPI secondary chamber has about 30 grams of propellant (booster and main) with an initial moisture specification of less than 0.20 wt. percent (representing 0.06 grams of water), the amount of added moisture could raise the propellant moisture significantly (for the secondary chamber propellant, from 0.20 wt. percent to 0.90 wt. percent). If this added moisture were concentrated in the 4 grams of booster tablets, the effect would be even larger (possibly raising the moisture content up to about 5 wt. percent).

The BakerRisk report concluded:

> Moisture permeation into a passenger inflator through the O-rings and igniter seals is a slow process, but may occur under high temperature and humidity conditions. The amount of moisture intrusion may be significant in certain climates over long periods of time. The presence of moisture, combined with temperature cycling, could deteriorate the propellant's mechanical strength and affect its ballistic performance when deployed.

XIV. 2013 to Present: "Beta" Events, Investigation, Regional Field Actions, and Further Recalls

A. *August 2013 to November 2014: The first "Beta Event" occurs in August 2013 and more follow*

In September 2013, Takata was notified that on August 6, 2013, a PSDI inflator ruptured in a 2005 vehicle in Florida. The inflator was manufactured in January 2005, making it the first inflator manufactured outside the 2000-2002 timeframe covered by previous recalls to rupture. Because of its manufacturing date, this event was the first rupture that could not be explained by pressing operations issues at Moses Lake or moisture exposure due to certain manufacturing processes from 2000-2001. Takata began to use the term "Beta Events" to refer to ruptures that were not covered by prior recalls and that were not explained by current root cause hypotheses. Conversely, Takata referred to field ruptures involving inflators included in prior recalls as "Alpha Events."

In December 2013, Takata was notified of a second Beta Event in Florida on September 7, 2013, involving a driver inflator manufactured in 2006. Notably, this event involved a PSDI-4 inflator. Only one other PSDI-4 inflator had previously ruptured, and that event had been attributed to overpacking.

In March and April 2014, Takata was notified of four additional Beta Events: two PSPI-L, one SPI, and one PSDI-4. The inflators were manufactured in 2002, 2003, and 2005. Beta Events continued throughout 2014.

B. *August 2013 to May 2014: Takata investigates the Beta Events and provides ongoing updates to NHTSA*

1. *January 2014: Takata and a vehicle manufacturer provide initial information regarding Beta Event 1 to NHTSA*

On January 22, 2014, a vehicle manufacturer and Takata met with NHTSA to discuss the August 6, 2013 field rupture event (Beta Event 1) and the companies' plans for investigation and remedial action. Takata explained that its investigation into Beta Event 1 was ongoing and involved analysis of the event sample, manufacturing records, and healthy parts produced from the same production period. Through inspection of the event inflator, Takata ruled out insufficient structural strength as a root cause of the rupture. Manufacturing records also indicated that the inflator met specifications for density, propellant load, and moisture.[41] Takata was obtaining field inflators from the same production period for live dissection and to assess ballistic performance during deployment. At the time of the meeting, a number of possible root causes had not been excluded, including excessive burning pressure (in the main and/or ignition propellant) resulting from unexpected high temperatures.

During this meeting, Takata also provided a breakdown of the PSDI/PSDI-4/4K field ruptures to date (*see* below). Takata noted that there were far fewer ruptures in the PSDI-4 (2 events out of 13 million inflators) than the PSDI (39 events out of 4.9 million inflators). It further stated that the PSDI-4 has design differences (*e.g.*, higher strength steel) and assembly differences from the PSDI, and that the field history indicates that the PSDI-4 performed differently with respect to abnormal deployments.

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[41] The inspection of the sample showed no apparent deficiencies in assembly and no ruptures along crimps or weld seams. The manufacturing records considered were propellant lot records, inflator lot records, and supplier quality control documentation for each lot.

PSDI and PSDI-4/4K Field History

- PSDI inflators from recalled population (global population)
  - 1.7 million inflators (built 2000-2001)
  - 37 events
- PSDI inflators outside of recalled population
  - 3.2 million inflators (built 2002 to present)
  - 2 events
    - Saudi Arabia event with 2003 built inflator due to overpack condition
    - Florida event with 2005 built inflator under investigation
- PSDI-4/4K inflators
  - 13 million inflators (built 2001 to present)
  - 2 events
    - EU event: 2001 built inflator due to overpack condition.
    - US event: 2006 built inflator under investigation.
    - These 2 events are not Honda vehicles

2. *May 2014: Takata gives presentation to NHTSA on first six Beta Events and suggests high absolute humidity ("HAH") theory*

On May 20, 2014, Takata met with NHTSA regarding the six Beta Events that it was aware of at that time. Takata told NHTSA that its "tentative conclusion" was that the Beta Events "reflect a combination of long-term exposure to [HAH] environment[s], and processing issues that may have influenced aging stability." In support of this "tentative conclusion," Takata pointed to the location of the Beta Events that had occurred thus far.

Takata stated, however, that the HAH environment theory required further investigation. Specifically, Takata stated that it needed to research the rate of moisture intrusion, the mechanism by which HAH environments alter the propellant's characteristics, and any differences between the different inflator types. Takata stated that it would test its theory by analyzing non-deployed inflators recovered from the field.

C. *Spring 2013 to January 2014: Hermeticity testing by Fraunhofer reveals SPI and PSPI manufacturing variability and potentially significant levels of moisture intrusion*

Takata also had engaged Fraunhofer to analyze the SPI and PSPI designs and specifications, as well as all available data and evidence related to the passenger inflator rupture events. Fraunhofer's initial conclusion was that there were "no clear indications for a common failure . . . based on collected information." However, Fraunhofer believed that hot and humid climates, while not the "sole cause" of the events were an "influencing factor which may elevate risk."

In a June 10, 2013 status report, Fraunhofer noted that it had dissected seven SPI and 47 PSPI inflators recalled from the field and detected "[r]ust and brown stains" on propellant parts. After receiving and dissecting seven additional PSPI inflators (61 total), Fraunhofer observed the following evidence of moisture intrusion:

- Propellant wafers sticking together (51 of 61 inflators)
- Stain marks (rust) on propellant (49 of 61)
- Rust on filter (11 of 61)

In addition, propellant wafers were broken in 10 of the inflators. Other potential manufacturing problems were noted. Fraunhofer also observed that the igniters are "made of a nylon plastic material (Polyamide) which is hygroscopic and may transfer water" when water concentration is not in a state of "equilibrium" inside and outside the inflator. Fraunhofer utilized the military standard to test the ability of moisture to enter new PSPI inflators through three pathways: (i) the O-ring; (ii) igniters (three varieties provided by different manufacturers); and (iii) the foil bust shim which separates the igniter from the propellant. In an interim update, Fraunhofer found a possibility of moisture intrusion through all three pathways, which would take the propellant slightly out of specification.

However, when Fraunhofer completed the same test cycles on the O-rings and igniters from 54 PSPI inflators and six SPI inflators made during 2003-2005 and returned from the field, these parts showed a rate of moisture permeation 2 to 2.5 times higher than the new baseline parts, resulting in a moisture content of nearly twice the specification limit. In the spring and summer of 2014, Takata supported regional field actions by vehicle manufacturers to recover inflators from the field, in part to confirm Fraunhofer's studies on moisture permeation.

D. *Spring 2014 to December 2014: Tests by Fraunhofer demonstrate that temperature cycling may speed up water migration into inflators and from booster to main 2004 propellant*

Fraunhofer performed additional testing on the process by which moisture may migrate within the inflator. Using a test setup designed to mimic an inflator, Fraunhofer found that a significant difference in moisture concentration inside and outside the test setup resulted in diffusion of water from higher to lower concentrations. The level of moisture absorption by the propellant varied based on the moisture levels outside the test setup, leak rate, and pressure changes inside the inflator caused by temperature cycling. Fraunhofer believed that this result was due, in part, to the fact that the 3110 propellant absorbs and desorbs water easily above 35ºC, while the 2004 propellant does so more gradually, allowing moisture to pass from the booster to the 2004 propellant during temperature cycling.

Additional water absorption/desorption testing by Fraunhofer confirmed that the 2004 propellant "is easily exchanging water with the surrounding atmosphere" and has the ability of absorbing water at an "unlimited" rate in high humidity environments, but that the amount of, and length of time that, water is retained in the propellant depends on the size and shape of the pressed propellant. As a result, 2004 propellant wafers, which have the lowest surface area to mass ratio, can absorb moisture gradually and retain it for longer than smaller 3110 and 2004 pellets, which absorb and desorb water more rapidly. This finding, again, supported the theory that temperature cycling may cause moisture build-up in the 2004 propellant.

E. *Spring 2014 to July 2014: Additional tests by Fraunhofer illustrate that moisture and temperature cycling (as in the HAH regions) may increase the porosity of the 2004 propellant*

Fraunhofer also used X-ray diffraction ("XRD") to identify structural changes in pure PSAN pellets and 2004 propellant pellets after temperature and humidity cycling tests. These changes could "modify its initial properties such as strength, porosity, fragility, etc."

The XRD analyses showed that humidity could cause uneven structural changes with "deeply detrimental effects in the behaviour of the material," such as reduced crush strength, increased burn rates, and resultant gas pressure.

Fraunhofer also used scanning electron microscopy ("SEM") and energy dispersive X-ray ("EDX") to measure structural changes to the 2004 propellant resulting from heat cycling and humidity exposure. Fraunhofer first tested PSAN pellets with increasing humidity. With additional exposure to humidity and heat cycling, propellant grains were becoming "dissolved and gluing together." This phenomenon caused "notable porosity."

Based on its prior research, Fraunhofer also utilized XRD, SEM, and EDX to analyze virgin PSPI propellant wafers compared to wafers returned from different areas of the United States.

Overall, Fraunhofer found that the results indicate a "clear effect of BHT on the stability of the wafers." Specifically, the BHT "dissolves in water and therefore reduces the amount of potassium on the PSAN, necessary for the stabilization of the [propellant in] phase III."[42] However, despite the theoretical possibility of AN phase IV, Fraunhofer has not identified AN phase IV in any of its artificially aged or field returned samples. In addition, Fraunhofer found "a clear influence of the climate of the selected region" (wafers from Puerto Rico revealing the largest crystal size, followed by Florida) "and of the position of the wafers [in] the inflator as well" (with larger crystal size observed in (i) the first wafer in closest contact with the igniter and booster charge and (ii) wafers from the secondary chamber).[43]

Moreover, Fraunhofer's analyses showed that "interfaces between AN and BHT are the most affected regions [of the wafers], where more material is lost during the different recrystalization processes." This "lack of material in large spaces" influences the mechanical stability of the wafer and "the burning rate." In addition, as Fraunhofer found previously, larger grain growth can potentially occur in the core of the wafer than on the surface ("non-homogenous grain size"). This phenomenon could potentially result in "the formation of porosity" in the pellet or wafer "related to the interaction between components." Again, this potential process is important because (i) porosity within pressed

[42] Phase stabilization of AN by potassium nitrate (KNO_3) essentially "freezes" the crystal structure at AN phase III, *i.e.*, there should be no volume change during temperature cycling. PSAN mixtures below 5% KNO_3, however, could exhibit formation of AN phase IV and destabilization.

[43] The larger crystal size in wafers from the secondary chamber likely is because the same amount of moisture intrusion occurs in both chambers, but with a smaller number of propellant wafers in the secondary chamber than in the primary chamber, each absorbing a relatively larger amount of water.

material "strongly determines or influences its burning behavior," and (ii) "different reactivity or burning rate along the wafer can lead to remarkable changes in the inflator behavior."

In summary, Fraunhofer's analyses revealed:

- A potential increase of crystal size in the 2004 propellant (i) with increasing humidity levels during cycling, and (ii) from HAH regions compared to newly pressed propellant;
- This potential effect is especially intense in the core of the wafer;
- Grain boundaries can become dissolved and glued to each other;
- Resulting in some cases the formation of porosity in the wafer.

A significant increase in the porosity of the propellant could lead to increased burn rates and increased gas pressure.

F. *May 2014 to November 2014: NHTSA requests regional field actions and the vehicle manufacturers comply*

1. *May 2014 to June 2014: Takata agrees to support regional field actions requested by NHTSA*

During a June 5, 2014 conference call, based on its May 20, 2014 meeting with Takata, NHTSA asked Takata to support field actions by vehicle manufacturers to replace suspect inflators in vehicles sold or registered in Florida and Puerto Rico, as well as other HAH areas. NHTSA suggested that the universe of inflators to be replaced should be based on the inflator manufacture date for the six Beta Events, with a replacement "buffer" period of twelve months on either side.

On June 11, 2014, Takata informed NHTSA in a letter that it would support the proposed regional campaigns. Takata agreed specifically to provide replacements for (i) PSDI and PSDI-4 inflators manufactured between January 1, 2004 and June 30, 2007, and (ii) PSPI, PSPI-L and SPI inflators manufactured between the start of production in June 2000 and July 31, 2004.[44] Takata agreed to support the replacement efforts in four areas with levels of HAH: Puerto Rico, Florida, Hawaii, and the Virgin Islands. Takata reiterated that the focus of its root cause investigation remained exposure to "exceptionally high levels of absolute humidity" in conjunction with "potential processing issues during certain manufacturing time periods that may influence aging stability."

On June 11, 2014, Takata identified seven affected vehicle manufacturers to NHTSA, and two weeks later it added two more vehicle manufacturers to the list after learning that those vehicle manufacturers had also received some of the covered inflators. Takata noted that, as of that time, it believed this was a complete list of affected vehicle manufacturers.

2. *June 2014 to November 2014: Vehicle manufacturers implement regional field actions*

With Takata supporting regional field actions in the HAH areas, on June 13, 2014, NHTSA contacted various automakers and urged them to conduct regional field actions in the HAH areas. From June to November 2014, in

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[44] These dates represent a buffer period slightly greater than the 12-month period that NHTSA requested.

response to NHTSA's request and in light of the Beta Events and related information provided by Takata, all of the identified vehicle manufacturers initiated regional field actions in the HAH areas covering vehicles equipped with the inflators identified by Takata.

On July 11, 2014, NHTSA and Takata met to discuss the regional field actions and other matters, including inflator production schedules, a technical analysis schedule, and issues related to data sharing amongst Takata, NHTSA, and the vehicle manufacturers. Regarding its analysis schedule, Takata stated that "it may take 3 to 4 months after receipt of field return inflators before we see patterns emerging in the data."

Takata participated with NHTSA in similar update meetings on August 19, September 16, and October 14, 2014 in which Takata provided updates regarding the status of the service part replacement schedule, the CT scanning program, leak and ballistic testing, and shared an analysis plan for returned field samples.

During a December 2014 meeting, Takata told NHTSA that approximately 11 percent of the necessary replacement kits for driver airbag inflators had shipped, and approximately 17 percent of the necessary replacement kits for passenger airbag inflators had shipped.

3. *June 2014 to November 2014: Vehicle manufacturers expand prior recalls*

In addition to the new regional field actions that were announced in June and July 2014, in 2014, several vehicle manufacturers expanded their prior 2013 recalls of PSPI and SPI passenger inflators.

In early June 2014, Takata informed vehicle manufacturers that the production records regarding when the auto-reject mechanism was operating may have been incomplete and that the methodology used to determine the 2013 recall range for the affected inflators was inadequate. Around this time, Takata also informed vehicle manufacturers about Beta Events involving passenger inflators not covered by the 2013 recalls. Takata requested that the vehicle manufacturers that had conducted 2013 recalls of passenger inflators expand their campaigns to cover the additional potentially affected inflators.

Five vehicle manufacturers expanded their passenger inflator recalls to include the range of inflators that Takata identified as potentially affected. Another vehicle manufacturer, which was not subject to the prior passenger inflator recall, notified NHTSA on July 3, 2014 of its intention to recall certain vehicles equipped with passenger inflator airbag inflators. That vehicle manufacturer attributed the alleged defect to "inflators which could have been assembled with improperly manufactured propellant wafers" and said that Takata had provided this explanation to the vehicle manufacturer on June 25, 2014.

G. *November 2014 to December 2014: NHTSA's request for a nationwide recall of certain driver inflators*

On November 17, 2014, NHTSA requested that Takata issue a Part 573 defect information report[45] that "unequivocally states" that a defect exists in a number of driver inflators, identified as all PSDI inflators manufactured from the start of production through December 31, 2006 and all PSDI-4 inflators manufactured from January 1, 2004 to December 31, 2008, regardless of whether the inflators were located in HAH areas. On November 18, 2014, NHTSA requested that five vehicle manufacturers expand their regional field actions to a nationwide recall covering

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[45] 49 C.F.R. Part 573 sets forth the requirements established by NHTSA for manufacturers to file defect information reports when they determine that a defect related to motor vehicle safety exists in the products they have produced.

vehicles equipped with the same population of driver inflators identified in the letter to Takata. By the end of December 2014, all five vehicle manufacturers had expanded their regional campaigns covering driver inflators to nationwide campaigns.[46]

Takata declined to issue a Part 573 report because it believed that there was no basis for a nationwide recall of the identified driver inflators. In response, NHTSA issued a "Recall Request Letter" to Takata on November 26, 2014, in which it stated that it had "tentatively concluded that a defect related to motor vehicle safety exists on a national basis in the subject driver's side air bag inflators."[47] The letter requested that Takata immediately submit a report that "identifies a defect in the driver's side airbag and is nationwide in scope." The letter stated that if Takata did not agree to a nationwide recall by December 2, 2014, NHTSA "may proceed to an Initial Decision that these vehicles contain a safety-related defect" and "may begin proceedings to seek penalties and remedies authorized by law."

On December 2, 2014, Takata responded to the NHTSA Recall Request Letter. Takata noted that under the statute and NHTSA regulations, only manufacturers of motor vehicles and replacement equipment—and not manufacturers of original equipment like Takata—are required to decide in good faith whether their products contain a safety-related defect and, if so, to conduct a recall. Takata also explained that the available data at that time did not support a nationwide recall covering all of the subject driver inflators, which would add 8 million more vehicles to recalls involving inflators which, as of that point, had experienced a failure rate of no more than .000006 failures per airbag deployment.[48] Takata explained that its testing of more than a thousand inflators up until then had resulted in no ruptures of inflators retrieved from outside the HAH regions. Takata stated that it would continue its efforts to provide replacement kits in the regions of concern. Takata added that its research and testing was ongoing and that it would take appropriate action if the evidence showed a safety defect beyond the scope of the current campaigns.

On February 20, 2015, U.S. Transportation Secretary Anthony Foxx announced that Takata would be fined $14,000 per day for failing to "fully cooperate" with the two Special Orders[49] NHTSA had issued to Takata, in that Takata had not fully explained the content of the more than 2.4 million pages of documents it had produced in response to the Special Orders.[50]

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[46] During the congressional hearing on December 3, 2014, a vehicle manufacturer stated it would expand its driver inflator campaign to all states but would continue to prioritize high-humidity areas. The vehicle manufacturer noted that it may rely on suppliers other than Takata. On December 10, 2014, another vehicle manufacturer expanded its driver inflator campaign nationwide; on December 18, 2014, a third vehicle manufacturer expanded its driver inflator campaign nationwide; on December 19, 2014, a fourth vehicle manufacturer expanded its driver inflator campaign nationwide; and on December 22, 2014, a fifth vehicle manufacturer expanded its driver inflator campaign nationwide.

[47] Under the procedures normally followed by the Office of Defects Investigation ("ODI"), ODI does not send a request for recall letter until after its defect investigation is concluded.

[48] This rate was estimated based upon a requested expansion of 8 million PSDI and PSDI-4 units, an average life of 8 years from time of manufacture, and an estimated air bag deployment rate of 0.5 percent of the population annually, divided into the two incidents referred to which NHTSA had referred in its letter to Takata.

[49] The Special Orders were issued on October 30 and November 18, 2014.

[50] *See* Feb 20, 2015 NHTSA Press Release, *available at*, http://www.nhtsa.gov/About percent20NHTSA/Press percent20Releases/2015/DOT-wants-new-enforcement-tools-for-nhtsa-and-fines-takata; *see also* "U.S. Fines Takata Over Air-Bag Investigation," *available at*, http://www.wsj.com/articles/takata-fined-for-not-cooperating-with-air-bag-probe-1424446134

H. *December 2014 to February 2015: Takata updates NHTSA on inflator testing*

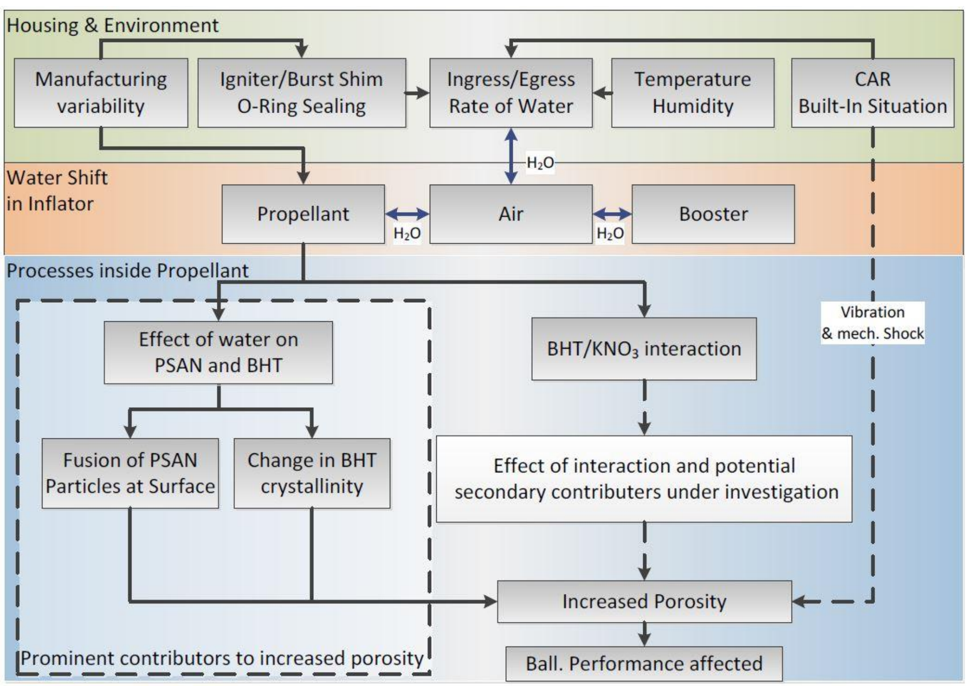
Takata updated NHTSA in mid-December 2014 and mid-January 2015 regarding the status of its investigation. Takata stated that it "[c]ontinued to see strong correlation of lab ruptures [in] the highest absolute humidity regions" but also noted that "[l]ong term aging and moisture alone may not be the only contributors to propellant performance change." Takata also observed that "[c]ertain inflators in certain vehicle models have a greater potential to rupture during lab testing than similar, or identical, inflators in other vehicle models."

Regarding the ongoing testing of field inflators as of that time, Takata stated that Beta population inflators experienced anomalies in the four-state HAH region 3 percent of the time, compared to zero percent outside that region. Furthermore, not all passenger inflator types performed equally, with the rate of rupture much higher in PSPI-L inflators (69 ruptures in 1,515 tests: 4.6 percent) in certain vehicle models as compared to PSPI inflators (3 ruptures in 1,598 tests: 0.19 percent) or SPI inflators (6 ruptures in 518 tests: 1.2 percent). The data further revealed that the PSPI-L-FD configuration used in certain vehicle platforms was by far the most likely to rupture in testing and accounted for 50 of the 58 ruptures seen in testing as of December 2014.

I. *February 2015: Fraunhofer's final summary report identifies manufacturing variability, temperature and humidity, rate of moisture ingress/egress, and the vehicle "built-in" environment as contributing factors to root cause*

In February 2015, Fraunhofer issued a final, summary report of its then-current findings regarding the root cause(s) of inflator ruptures. Fraunhofer's overall fault tree analysis is depicted below:[51]

Fraunhofer's February 2015 Fault Tree Analysis



[51] Fraunhofer's early studies considered the chemical degradation of phase-stabilized ammonium nitrate ("PSAN"). However, the studies found no loss of stability in the PSAN as the propellant aged and, as such, "the possibility of chemical degradation can be set aside for further root cause analysis because of these findings."

As the fault tree analysis shows, Fraunhofer's investigations pointed to increased porosity in the propellant wafers, which, in turn, causes the propellant to perform more aggressively.

Fraunhofer's initial analyses involved whether (and how) moisture could intrude into the inflators despite the successful passing of helium leak tests. Fraunhofer found areas of high absolute humidity[52] and high temperature (with small temperature differences throughout the day) allowed for the highest rates of moisture entering the inflators. Fraunhofer identified the igniter assembly in the PSDI and PSPI inflators as an entry point for moisture permeation. Further, in the PSPI inflators, the O-ring seal also allows for moisture diffusion over time (a similar O-ring is used in PSDI). Finally, Fraunhofer observed that the built-in environments in specific vehicles appear to affect moisture ingress/egress rates. Fraunhofer's research suggested that, in the absence of manufacturing problems, HAH and high temperature cycles are necessary, but not necessarily sufficient, to cause inflator ruptures.

Fraunhofer's research identified two broad factors that may increase the propellant's porosity once moisture has entered an inflator. First, Fraunhofer believed moisture is impacting the crystal structures of PSAN. Tests show that when the 2004 propellant wafers are exposed to water over time, the PSAN particles are growing and fusing together. In addition, the BHT particles are becoming more crystalline. Fraunhofer believed these two processes, especially at the wafer core, increased the internal porosity of the propellant and connected pores that may grow sufficiently large to increase surface area during a deployment.

Second, moisture may be catalyzing an interaction between the BHT and potassium nitrate ("KNO_3"). Fraunhofer's research showed BHT may be exchanging an ion with KNO_3 in the 2004 propellant, thereby creating a potassium salt of BHT plus a non-phase-stabilized AN particle. In addition, if the BHT is drawing KNO_3 ions away from the PSAN crystal lattice, there may be a breakdown of the PSAN independent of whether there is a potassium salt formed.

Both of these events could degrade the mechanical integrity of the 2004 propellant. In turn, this loss of mechanical integrity could cause a breakup of the propellant wafers, especially during the ignition process, thereby increasing surface areas and burn rates. However, Fraunhofer was careful to point out that "[d]espite the theoretical possibility[,] presence of AN phase IV nor breakdown of AN phase stabilization could not be confirmed during analysis of artificial aged samples or field samples of the 2004 propellant."

Finally, Fraunhofer identified a third general factor for further investigation—the built-in environment of specific vehicles. Fraunhofer believed the variability in the built-in vehicle environment leads to varying vibration and shock levels in the inflator. Fraunhofer also believed that varying module designs may contribute to moisture's ability to enter and move within the inflator. A module tightly enclosed in a well-sealed dashboard would be less susceptible to moisture infiltration. Fraunhofer believed the data on field events provided by the Product Safety Group at Takata, which showed substantial variability in event rates among vehicle manufacturers using the same inflators, was a "clear indication for this theory."

In February 2015, after Fraunhofer issued its final summary report, Takata and Fraunhofer updated NHTSA on the results of their ongoing testing. As a result of these tests, Takata presented three key findings to NHTSA. First, the company found that "[l]ong-term exposure to persistent high absolute humidity" was a "clear factor" in root cause. Second, Takata found "PSDI-4/4K (driver-side) inflator ruptures in testing and the field are exceedingly rare." Third, Takata found "[p]assenger-side test outcomes vary significantly between [vehicle makes] and vehicle models, even

[52] Absolute humidity is the water concentration in the air. Relative humidity is a measure for the current humidity concentration relative to the maximum concentration for the actual temperature.

with common inflators." Notably, "[i]nflators from different [vehicle manufacturers] show a different response" to humidity and temperature conditions.

Takata and Fraunhofer also provided an update to vehicle manufacturers in March 2015 regarding the results of their root cause testing. Takata stated that the underlying cause of the field events required three elements: (1) "a decade-scale moisture migration into the inflator driven by local high absolute humidity conditions," (2) "a slow change in the propellant physical conditions as evidenced by internal PSAN grain growth, pore agglomeration and potentially ionic migrations in the presence of elevated internal moisture and high temperature conditions, which are strongly influenced by certain vehicle platforms," and (3) "a resulting threshold-based porous burning phenomena related to the change in propellant physical conditions which causes high pressures, occasionally resulting in ruptures." Takata also stated that validation testing according to vehicle manufacturers' specifications may not sufficiently test for this process in high absolute humidity environments. Takata added that there may be isolated instances of manufacturing departures in certain cases, including issues related to seal integrity that may result in moisture intrusion and subsequent performance degradation.

J. *May 2015: Takata issues DIRs and enters into Consent Order with NHTSA*

On May 18, 2015, based on discussions with NHTSA, Takata issued Defect Information Reports covering PSDI, PSDI-4, and PSDI-4K driver inflators and certain SPI, PSPI, and PSPI-L passenger inflators.[53] The driver inflator DIR (No. 15E-040) covered each inflator for all years of production, nationwide. The SPI passenger inflator DIR (No. 15E-041) covered inflators installed in Model Year 2008 and earlier vehicles, nationwide. The PSPI and PSPI-L passenger inflator DIRs (Nos. 15E-042 and 15E-043) covered inflators only in the HAH region[54] and only as to certain vehicle makes and models, as reflected below:[55]

PSPI:

- Certain specified vehicle makes and models from Model Years 2001 through 2006

PSPI-L:

- Certain specified vehicle makes and models from model Years 2003 through 2007

In all of the DIRs, Takata stated that the propellant "in some of the subject inflators may experience an alteration over time, which could potentially lead to over-aggressive combustion," which "could result in the body of the inflator rupturing upon deployment." Takata also stated that its investigation to date had found that the potential for such ruptures may occur in subject inflators after "several years of exposure to persistent conditions of high absolute humidity." Takata noted that other factors, such as manufacturing variability, may be relevant as well.

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[53] DIR Nos. 15E-040, 15E-041, 15E-042, and 15E-043.

[54] In contrast to the HAH region used in the regional field actions, these DIRs applied to Florida, Puerto Rico, the U.S. Virgin Islands, Hawaii, the Outlying U.S. Territories, Texas, Louisiana, Georgia, South Carolina, Alabama, and Mississippi.

[55] The PSPI and PSPI-L inflator DIRs noted that if ordered by NHTSA, based on the results of further testing and engineering analysis, the recalls recommended in the DIRs could be expanded potentially to include the rest of the U.S.

The PSPI and PSPI-L DIRs noted that Takata's test results "indicate that even with identical inflator designs, the likelihood of a potential rupture is greater in certain vehicle models, including the models identified [in the DIR], due to factors that have not yet been identified." The SPI DIR noted that Takata had found "a small number of tape seal leaks in SPI inflators manufactured prior to 2007," which were discovered during leak testing in 2014. Such a leak, Takata stated, could "increase the potential for moisture to reach the main propellant wafers, possibly in areas outside of the highest absolute humidity States."

On May 18, 2015, the same day as the DIRs were issued, Takata entered into a Consent Order with NHTSA. The Consent Order provided, among other things, that:

- Takata would continue to cooperate with NHTSA in its regulatory actions, including conducting reasonable testing and coordinating recall and remedy programs with the relevant automobile manufacturers;
- Within 60 days, Takata would submit a plan to NHTSA regarding implementation of the recall that, to the extent reasonably possible, maximizes recall completion rates. Takata would also propose a plan to provide NHTSA with test data regarding the service life and safety of the replacement inflators currently being manufactured by Takata;
- NHTSA's investigation would remain open until it makes a determination that all issues related to its investigation—including the scope of the recalls and adequacy of the remedy—have been satisfactorily resolved.[56]

K. *Fall 2015: Fraunhofer provides update on root cause investigation*

In the fall of 2015, Fraunhofer provided updates on the latest results of its ongoing root cause investigation. The testing focused on four areas:

- Replicating the porous burning effect seen in the field through artificial aging;
- Determining the location and rate by which moisture is diffusing and permeating into inflators;
- Investigating how moisture absorbs/desorbs from the booster propellant into the main propellant; and
- Analyzing field return inflators to determine a life-time prediction model for Takata inflators

On the first issue, in order to replicate and characterize the porous burning effect through artificial aging, Fraunhofer conducted temperature cycling on several tablet and wafer types, with varying amounts of moisture added. It then conducted SEM and XRD analysis on the wafers, as well as ballistic testing.

The XRD testing showed grain growth at the surface of the wafer but not in the core. This result differed from the field returned inflators, which show significant grain growth in the core of the wafer in addition to the surface. It indicated that Fraunhofer's testing methodology, while producing grain growth at the surface, was not replicating the field conditions as to the core of the wafer. The SEM results confirmed this finding, with changes in the core of the wafer being less pronounced than at the surface.

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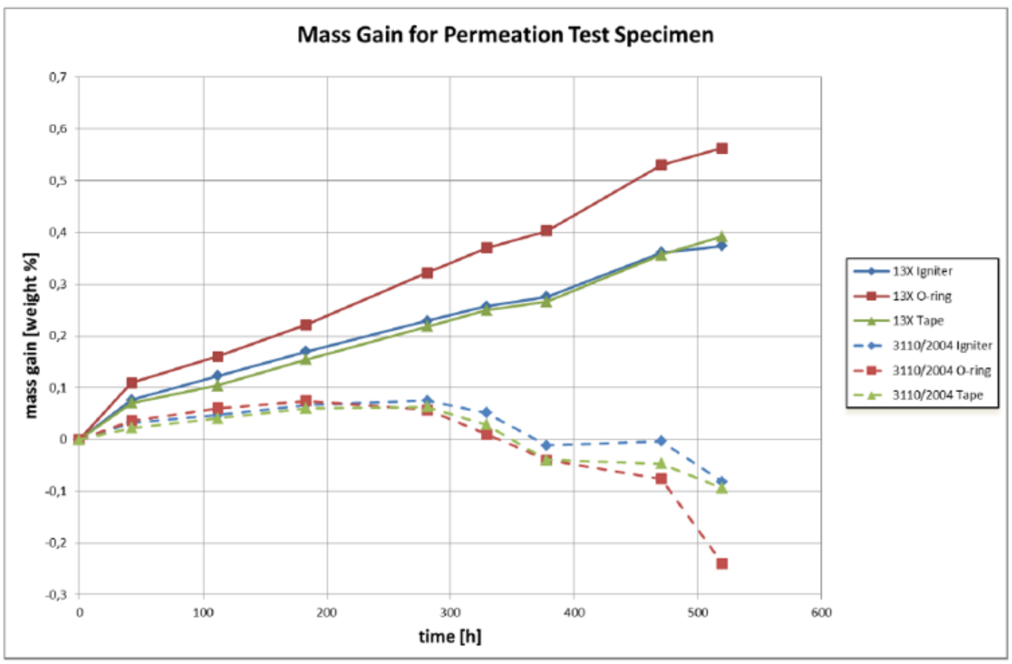
[56] *See* NHTSA Consent Order, May 18, 2015.

Burn rate analysis showed an increase in burn rate in the middle pressure ranges, followed by a decrease in burn rate at the higher pressure levels. This drop in burn rate at high pressures differed from what is seen in field inflators, where pressure continues to rise at high pressure levels. Again, this result also indicated a lack of porosity in the core of the wafers; porous burning occurred at medium pressures, but because of the lack of porosity in the core, the burn rate decreased at higher pressures.

Fraunhofer believed that the cause of the lack of moisture permeation into the core of the wafer was due to the fast speed of the thermal cycling test used. Fraunhofer believed that fast thermal cycling does not permit moisture to penetrate into the core of the propellant wafer, which resulted in porosity between the surface and the core, but not in the core itself. Fraunhofer is currently running additional testing that will attempt to replicate field conditions more closely by changing the thermal cycling and moisture conditioning process.

On the second issue—the location and rate by which moisture is permeating into and out of inflators—Fraunhofer found that water was transferring more rapidly through the O-ring, followed by the igniter and tape seal, which showed a similar rate. Furthermore, moisture was entering the inflator faster when 13X desiccant was in the inflator, due to the desiccant's absorption of moisture causing a higher concentration gradient, though there is no indication the desiccant's neutralizing effect was compromised. Both relationships can be seen in the graph below.[57]



Moisture permeation through O-ring, igniter, and tape seal, with and without 13X.

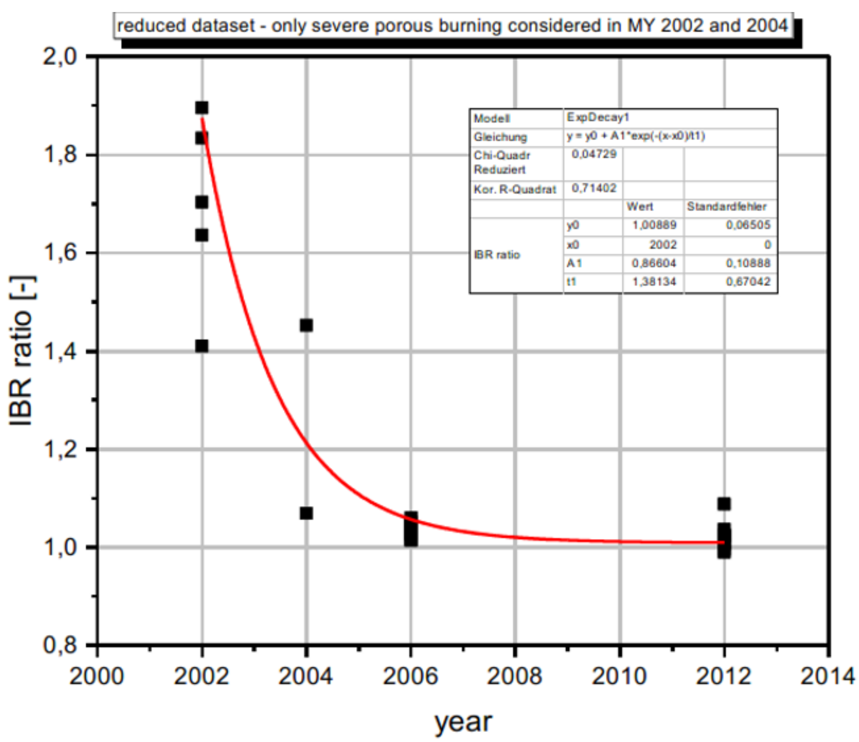
One phenomenon displayed in the graph is the reduction in moisture in the inflators without 13X when the conditioning time passes 300 hours. Fraunhofer is confirming this result, but believes a possible explanation is the increase in permeation rates due to plastic components aged by thermal cycling, which would enable higher moisture egress rates at elevated temperatures. In other words, when plastic components are aged, they may leak moisture

[57] Fraunhofer tested diffusion rates in addition to permeation rates. Both diffusion and permeation exhibited the same relationships.

out of the inflator at high temperatures, resulting in a loss of moisture. Fraunhofer suggested that testing be done on a larger sample size of inflators so that manufacturing variability can be taken into account.

On the third issue—the absorption and desorption characteristics of 2004 and 3110 propellant—Fraunhofer tested both types of propellant in a closed test chamber with varying levels of moisture added. Fraunhofer then analyzed the ambient humidity in the atmosphere of the chamber at different temperatures. Fraunhofer found that 3110 propellant is preferentially absorbing moisture in the inflator until it reaches a threshold concentration of 2.5 wt. percent. At that point, relative humidity levels inside the inflator reach a point where the 2004 propellant begins absorbing moisture. Fraunhofer found that this preferential moisture absorption by the 3110 propellant, in combination with the fact that it takes 0.2 wt. percent moisture inside the 2004 propellant before degradation begins, results in extreme long delay times for conversion to porous burning.

On the fourth issue—the creation of a service life prediction model for Takata inflators—Fraunhofer conducted ballistic testing on 20 field returned inflators from south Florida with different manufacturing dates (all from the same inflator type and "worst case" vehicle model). Fraunhofer then compared the burn rates of these field inflators to the burn rate of virgin 2004 propellant. Fraunhofer found that there was no porous burning in wafers from 2006 or younger. For inflators older than 2006, Fraunhofer found that the burn rate was increasing with age. This result can be seen in the graph below, which plots the relative increase in burn rate by inflator year, with the burn rate of newly made propellant expressed as 1.0.

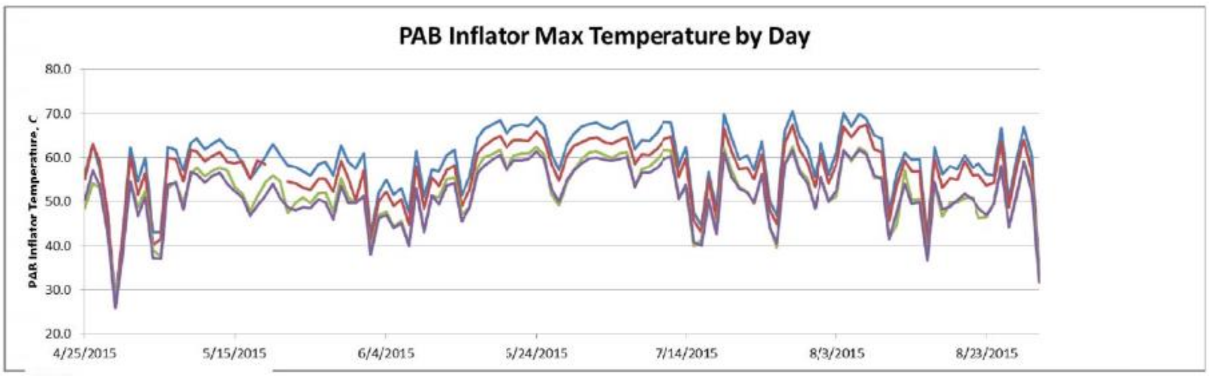


Burn rate increase over baseline increases exponentially for inflators older than 2006.

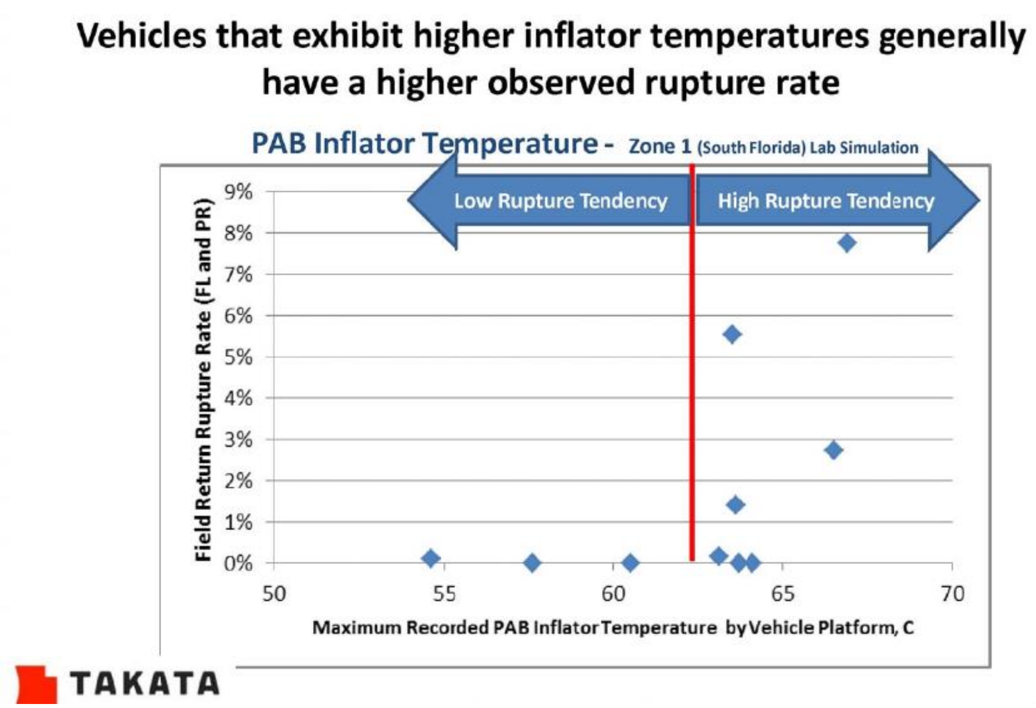
In accord with the above exponential curve, Fraunhofer found that approximately 80 percent of wafers from 2002 showed an increased burn rate over baseline. Wafers from 2004 exhibited porous burning in only 30 percent of inflators. Fraunhofer suggested that Takata employ this methodology on a larger sample size of field returned inflators.

L. *September 2015: Takata presents latest findings and proposes maximum internal vehicle temperature as a potentially critical factor*

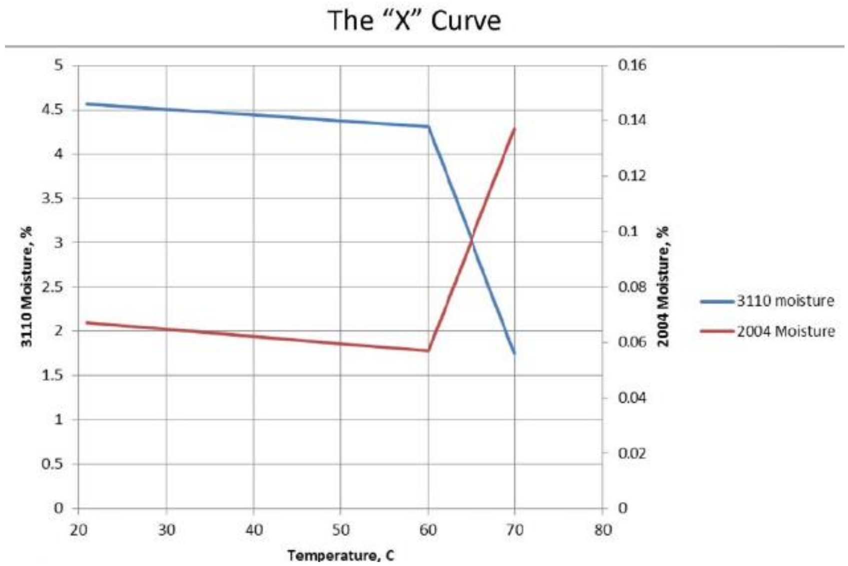
On September 29, 2015, Takata updated its vehicle manufacturer customers on the state of its investigation. The root cause statement provided at the March 2015 update to vehicle manufacturers remained unchanged, and Takata provided additional data and explanation of the potential for ingress and movement of moisture and effects upon the propellant. First, Takata stated that its in-vehicle testing had not shown a correlation between the inflator's rupture rate and the humidity in the vehicle or moisture content inside the inflator. Rather, of all of the measurements taken, "the passenger inflator max temperature has the strongest correlation to the field outcome." On this point, Takata found that the maximum temperature varies between vehicles in a small but "potentially critically important" way. The chart below shows the interior temperatures of different vehicles in Miami over a period of months.



As can be seen, only in certain vehicle types does the interior temperature regularly rise above 60ºC. This fact appears to be significant, Takata observed, because rupture rates appear to increase as the maximum passenger airbag temperature rises above 60ºC, as show below:



This increased rupture rate above 60ºC, Takata observed, may be related to Fraunhofer's findings regarding the tendency of 3110 propellant to absorb water preferentially, which tend to show that 3110 desorbs its water and transfers it to 2004 propellant at higher temperatures:



These observations indicate a rapid transition of moisture from the 3110 propellant into the 2004 propellant when temperatures exceed 60ºC. This transition appears to occur more rapidly as the amount of moisture in the 3110 increases.

From this, Takata observed that the current understanding of the field failures is that:

- Persistent exposure to high absolute humidity allows moisture to be absorbed into the 3110 booster propellant;
- Moisture is stored in the 3110 propellant until 60ºC is reached;
- In certain vehicles and in certain climates, the passenger airbag temperature regularly rises above 60ºC, forcing water from the 3110 propellant into the 2004 propellant;
- The persistent exposure to moisture in the 2004 propellant in these inflators may cause a change in the burning characteristics, which can lead to rupture.

M. *November 2015: Takata enters into an additional Consent Order with NHTSA*

On November 3, 2015, Takata entered into an additional Consent Order with NHTSA. The Order stated that NHTSA had "discovered facts and circumstances indicating that":

(1) Takata failed to provide timely notice to NHTSA of one or more safety-related defects relating to the 2013-2015 recalls;

(2) Takata produced testing reports that contained selective, incomplete, or inaccurate data;

(3) Takata failed to clarify inaccurate information provided to NHTSA; and

(4) Takata failed to comply fully with NHTSA's Special Orders from October 30 and November 18, 2014.

In the Consent Order, Takata admitted that it did not satisfy the applicable notice provisions regarding the defect underlying the 2013 to 2015 recalls (item 1 above), although it noted that it did not believe such notice was required at the time. Takata further admitted that it failed to provide timely explanations of certain documents produced to NHTSA pursuant to the October 30, 2014 and November 18, 2014 Special Orders (item 4 above).

The Order imposed a civil penalty of $70,000,000 that was to be paid over the course of several years. The Order authorized NHTSA to penalize Takata an additional $60,000,000 if Takata failed to comply with certain requirements to phase out the use of non-desiccated PSAN inflators, and an additional $70,000,000 if NHTSA determines that Takata entered into a new contract for the manufacture and sale of any PSAN inflator or committed a violation of the Safety Act not disclosed to NHTSA as of the date of the Order.[58]

The Order requires that Takata phase out non-desiccated PSAN inflators according to an agreed schedule. As of January 2016, Takata has greatly exceeded the requirements of the Order in this regard. The Order required that by December 31, 2015, non-desiccated PSAN driver inflators must account for less than 50 percent of Takata's driver inflator sales for use in U.S. vehicles. In certifying compliance with this requirement, Takata calculated that between October 2015 and January 2016, less than 2.5 percent of driver inflators Takata shipped each month for use in U.S. vehicles were non-desiccated inflators.

Under the Consent Order, desiccated inflators ordered under supply contracts entered into prior to October 31, 2015, may continue to be sold, subject to further safety testing.[59] The Order also requires that Takata: (1) conduct service life testing for both desiccated and non-desiccated inflators and update NHTSA as to the results, (2) submit the present investigation report to NHTSA, (3) confirm the termination of certain employees, (4) appoint a Chief Safety Assurance and Accountability Officer who shall have independent authority to oversee safety improvements, (5) ensure that its whistleblowing process encourages its employees to report potential safety related defects expeditiously, (6) meet with NHTSA every 90 days to discuss steps it has taken pursuant to the Order, and (7) retain an Independent Monitor who has authority to review and assess compliance with the Order.[60]

On the same day, November 3, 2015, NHTSA issued a Coordinated Remedy Order, in which it found that the vehicle manufacturers' recall programs must be accelerated in order to complete inflator replacements within a reasonable period of time. To that end, NHTSA defined the prioritization for inflator replacements:

- Priority Group 1: Highest risk vehicles, generally those from model years 2008 or older that have spent time in the high absolute humidity region and that have either a driver inflator or both driver and passenger inflators that are subject to the recalls.

- Priority Group 2: Intermediate-high risk vehicles, generally including all recalled vehicles with the subject driver inflators that are not in Group 1 and recalled vehicles with certain subject passenger inflators that have higher rupture frequency and have spent time in the high absolute humidity region.

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[58] NHTSA Consent Order, November 3, 2015, at ¶¶19-23.

[59] *Id.* at ¶¶24-26.

[60] *Id.* at ¶¶ 28, 33, 34, 35-47.

- Priority Group 3: High risk vehicles, generally including recalled vehicles outside the high absolute humidity region with only subject passenger inflators, or those in the high absolute humidity region with certain subject passenger inflators that have lower risk of rupture.

- Priority Group 4: Vehicles that will require an interim remedy (a remedy inflator that may contain the same defect as the inflator subject to recall) because alternate parts are not available.

NHTSA ordered that the vehicle manufacturers must acquire a sufficient supply of replacement inflators for each group by the following dates:

- Priority Group 1: March 31, 2016

- Priority Group 2: September 30, 2016

- Priority Group 3: December 31, 2016

NHTSA further ordered that the vehicle manufacturers shall have the following target deadlines for completion of all inflator replacements:

- Priority Groups 1-3: December 31, 2017

- Priority Group 4: December 31, 2019

NHTSA ordered that the vehicle manufacturers must provide within 90 days a plan for maximizing inflator replacement rates. Finally, NHTSA ordered that Takata shall cooperate with NHTSA's Coordinated Remedy Program and work with NHTSA to coordinate and accelerate the replacement of airbag inflators.

N. *January 2016: Takata issues DIRs covering non-desiccated PSDI-5 and SDI Inflators*

On January 25, 2016, Takata issued two additional DIRs.[61] The first contemplated a recall of all non-desiccated SDI driver airbag inflators in the United States from the start of production through the end of Model Year 2014. Takata estimated the number of vehicles affected at 1.2 million. Takata described a number of field ruptures and other events involving SDI inflators.

The second DIR issued on January 25, 2016 contemplated a recall of all non-desiccated PSDI-5 inflators from the start of production through the end of Model Year 2014. Takata estimated the number of vehicles affected as 3.9 million. Takata stated that although it was aware of four ruptures of non-desiccated PSDI-5 inflators that occurred during testing, it was not aware of any field incidents in which a PSDI-5 inflator had ruptured.

O. *Late 2015 to early 2016: Fraunhofer and Takata find that manufacturer validation tests do not simulate the moisture intrusion seen in the field, and Takata begins work to develop a new inflator validation specification*

Throughout Takata's root cause investigation, a recurring question has been why validation testing required by vehicle manufacturers—and conducted by Takata—did not predict or adequately anticipate the long-term propellant degradation phenomenon associated with ruptures seen in the field.

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[61] DIR Nos. 16E-005 and 16E-006.

To answer this question, Fraunhofer studied the differences in inflators retrieved from the field from those put through vehicle manufacturer validation environments. Specifically, Fraunhofer compared PSPI inflators subjected by Takata to a series of vehicle manufacturer validation environments to those retrieved from Florida. In a report dated July 31, 2015 (and updated November 30, 2015), Fraunhofer described its findings. Overall, Fraunhofer found "remarkably lower concentrations" of moisture in inflators after vehicle manufacturer validation testing as compared to those seen in the field. As can be seen in Figure 3-3 below, the average moisture was far higher in the field return sample than after USCAR sequential testing.

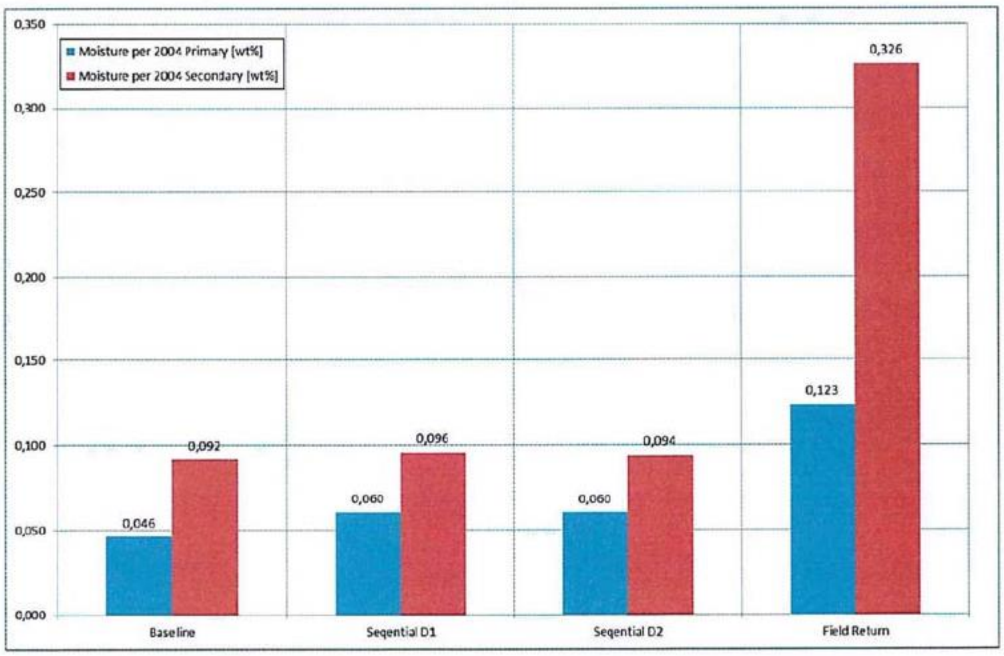


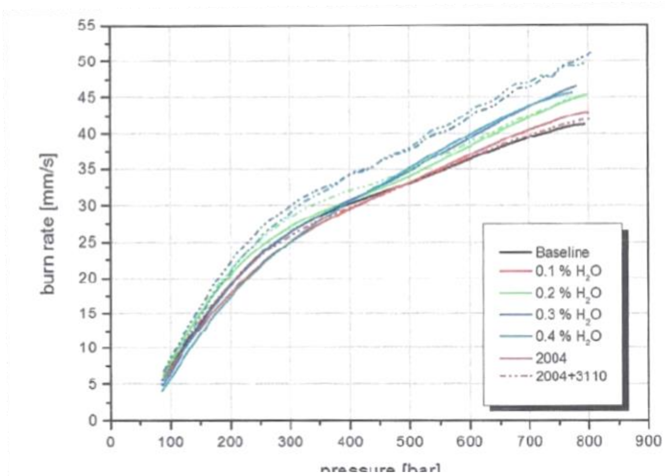
Fig. 3-3: Moisture inside inflators referred as moisture of 2004 propellant mass before / after USCAR sequential tests and data determined after life dissection from field return inflators (only Florida)

Overall, environmental validation tests were able to generate only 50 to 60 percent of the average field return's moisture in the primary propellant, and only 30 to 50 percent of the moisture in the secondary propellant. Fraunhofer found that the vehicle manufacturer validation tests "did not reach the levels [of moisture] high enough to generate the porous burning effect over time."

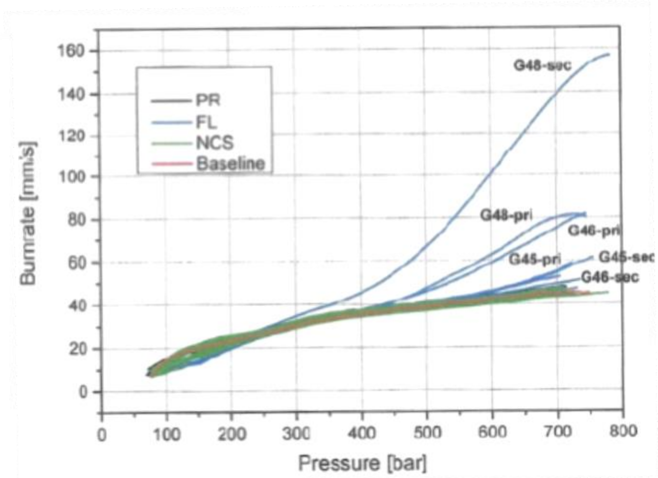
Fraunhofer stated that the low levels of moisture observed in vehicle manufacturer validation tests could be explained by the drying effect of temperature cycling required during those test procedures. Specifically, when an inflator that has been heated for a period of time is then placed in a colder environment, as is done during vehicle manufacturer thermal cycling, the reduction in ambient temperature results in a pressure drop inside of the inflator. This pressure drop draws cold ambient air into the inflator. Because the cold ambient air has much lower moisture than the warm air inside the inflator (due to the correlation of water vapor with temperature), the air being drawn into the inflator is relatively dry, resulting in a drying effect within the inflator.

In January 2016, Takata released a similar report on findings regarding the differences between the inflators that had undergone vehicle manufacturer validation testing and field-returned inflators. Like Fraunhofer, Takata found far higher levels of moisture in the field inflators. When looking at the 3110 propellant—which preferentially absorbs water—Takata found that the field-returned samples had 4 to 8 times higher moisture than the vehicle manufacturer validation test units. Calculating this difference over the life of the inflator shows that the field environment moves nearly 40 times as much water into the inflator than vehicle manufacturer validation tests.

The report also discussed testing regarding the difference in burning characteristics between field returns and propellant put through artificial cycling tests conducted by Fraunhofer intended to recreate porous burning. As can be seen in the Fraunhofer chart below on the left, increased moisture due to artificial cycling results in a roughly uniform increase in burning rate across the entire range of pressures. The Fraunhofer chart on the right, by comparison, shows what is seen in the field: a highly non-uniform increase in burning rates that is exhibited only in the high pressure ranges.



Artificial cycling tests



Field return testing

Takata noted that this effect can also be seen in the internal chamber pressure within an inflator. The internal pressure of an inflator increases steadily and predictably with increasing propellant degradation due to increased moisture and temperature cycling during validation testing. Conversely, the results of the field returns do not follow the same characteristic.

In sum, Takata concluded that vehicle manufacturer validation tests do not degrade the propellant in the same manner as observed in the aged field returns. Accordingly, Takata concluded that vehicle manufacturer validation environments are not useful in determining the expected life of the inflators in the field.

As a result of these findings, Takata, Fraunhofer, and the industry as a whole have begun discussions on a potential new specification, different from those that vehicle manufacturers currently require, that would be designed to replicate more closely the types of environments seen in the field.

P. *March 2016: Takata and Fraunhofer report updated findings to NHTSA and vehicle manufacturers*

In March 2016, Takata and Fraunhofer updated NHTSA and the automakers with the latest data regarding root cause analysis and lifetime prediction modeling.

First, Takata reported that it had done ballistic testing on over 220,000 field inflators, completed 27,000 live dissections, and conducted 13,000 CT scans. Takata stated that it planned to analyze this data and determine what percentage of inflators from various regions and ages are showing abnormally high pressure values. Using this data, Takata will statistically analyze the values and categorize the risk of inflator rupture based on the year of manufacture, location in the country, make and model of vehicle, and type of inflator. Takata noted that the initial results of its analysis show that temperature, age, and moisture continue to be key contributors to degradation of propellant. The data provided further evidence of the variation on inflator service life according to specific models of vehicles.

Takata also described its plans to analyze inflators that were not previously subject to recall. As for non-desiccated inflators, Takata stated that there were at the time approximately 32 million SPI, PSPI, PSPI-L, PSPI-6, and PSPI-2 not covered by recalls. Takata stated that it was continuing to analyze these inflators through voluntary field actions.

As of March 2016, there were also approximately 40 million desiccated inflators not covered by recalls. As to these inflators, per the provisions of the Consent Order, Takata recommended that the vehicle manufacturers conduct voluntary actions to return 1,000 of several different types of inflators to Takata for testing. Takata recommended that the returns be from Florida and from the oldest vehicle models, due to the increased risk from these inflators based on their age and exposure to high absolute humidity.

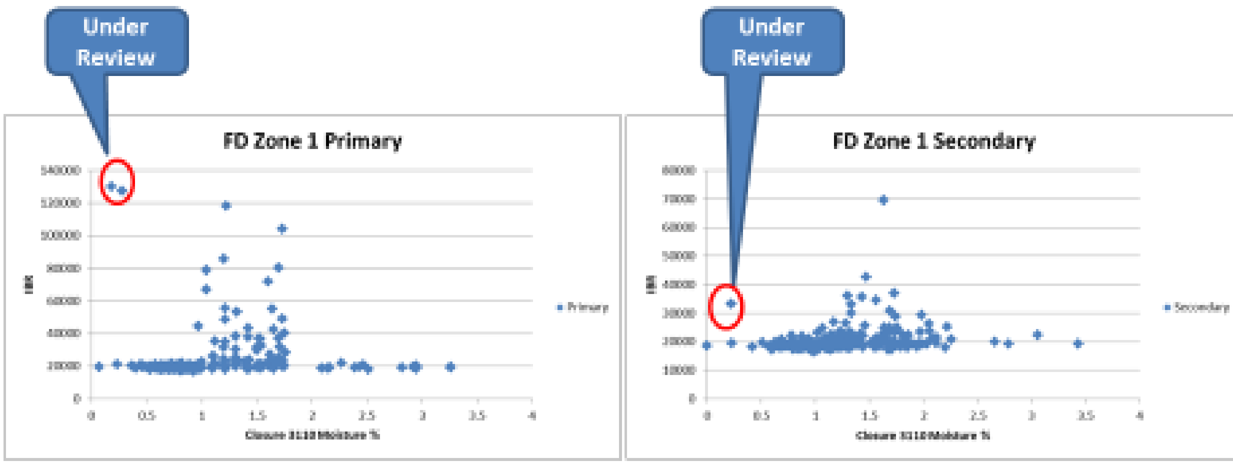
Fraunhofer also updated its latest findings. Fraunhofer shared new data regarding the regional differences in the moisture content of inflators. Fraunhofer found that the distribution of moisture values (as measured in the 3110 booster propellant) increases by zone of the country, with Florida (Zone 1) being distributed towards higher moisture values, and Zone 4 being distributed towards lower moisture values. Fraunhofer also found that the relative distribution for all zones is shifted towards lower moisture values in vehicles with lower rupture rates, although this shift was minor and is not considered significant enough to explain the differences in rupture rates.

In conjunction with Fraunhofer, Takata also provided an update to its ongoing root cause investigation. First, Takata described its latest testing regarding the transfer of moisture between 3110 and 2004 propellant. Takata reported that the data collected supported a conclusion that a threshold moisture and temperature exist, below which, no moisture transfer occurs between the 3110 and 2004 propellant. Takata also confirmed its previous finding that the transfer point moves to colder temperatures as the moisture level increases. Takata noted that this moisture transfer began occurring as low as 35ºC when high levels of moisture (3.7 percent) were added.

Takata also provided an update on its latest closed-vessel ballistic tests, which tested the burn rate and moisture content of 320 field inflators that were collected from high rupture areas of the country. As demonstrated in the charts below, the data supports Takata's belief that there is a threshold moisture level before the propellant begins to degrade.

Moisture Influence on Burning Rate

- There appears to be good support for the existence of a moisture threshold needed to convert the propellant.
- We typically do not observe HIGH burning rates with LOW moisture, but there are three test cases that are currently under examination.



With the exception of the three tests circled in red, increases in burn rate are not seen until moisture levels reach approximately one percent. Takata also again confirmed that its testing is showing that moisture alone, without aging, does not alter burn rates. Takata reiterated that moisture is necessary but not sufficient; high temperatures are also required.

Finally, Takata presented its initial findings on the estimated service life of desiccated inflators. By calculating the rate that moisture enters the inflator, and comparing it to the amount of moisture that Takata's desiccant can hold, Takata was able to give an initial estimate of how long the desiccant would continue to absorb moisture. Takata used a worst case scenario for its estimates: the 99th percentile of moisture intrusion for SPI inflators in the HAH zone.

Takata calculated that under these circumstances, it would take 12.5 years for the desiccant to become fully saturated. Again, this assumes a high vehicle temperature and 99th percentile moisture ingress rate. Takata also provided similar estimates for vehicles with different inflators, and in different areas of the country. The time to full saturation varies between 12.5 years and 35.3 years based on area of the country.

Takata explained that these calculations are only initial estimates that rely on certain assumptions that are not perfectly understood. These assumptions include the relative change in the moisture ingress rate as moisture increases, the relative holding capacity of the desiccant in a sealed inflator at various temperatures and humidity levels, and the changes in ingress rate as the inflator ages. Further testing is underway to answer these outstanding questions and provide better estimates for the service life of Takata's inflators.

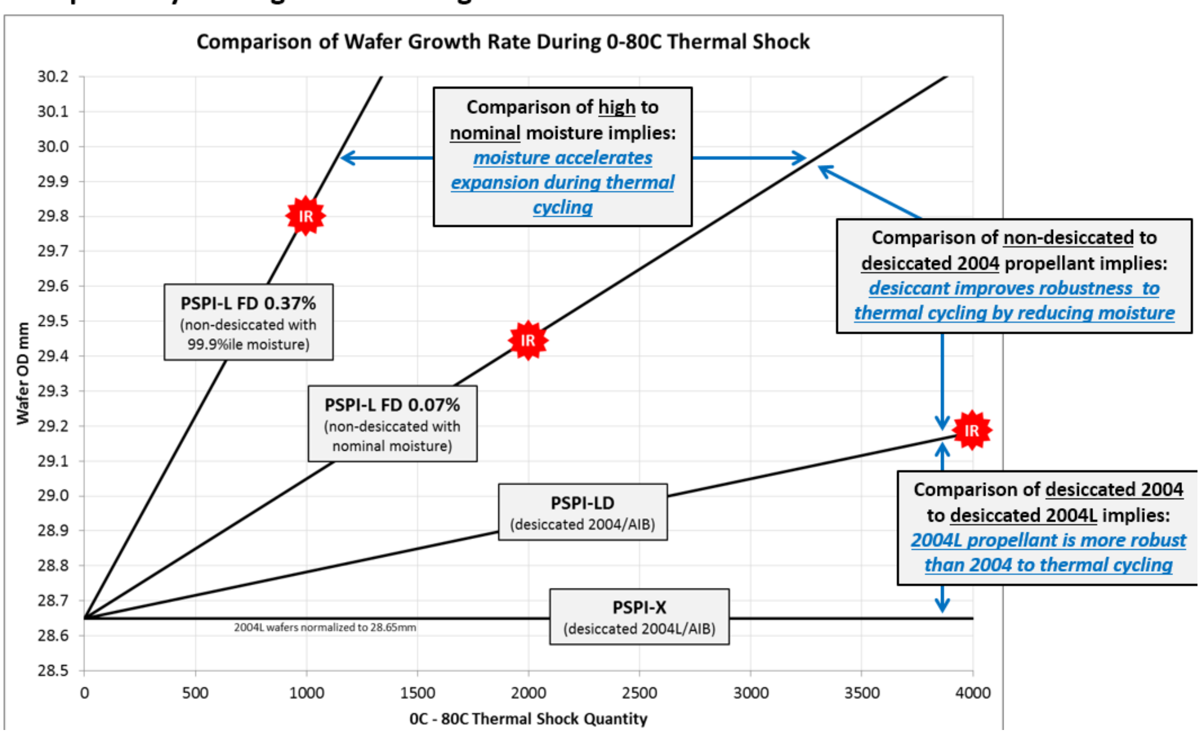
Finally, Takata discussed the results of testing it conducted regarding the relative robustness of desiccated passenger inflators versus non-desiccated versions. To test this, Takata conducted thermal shock testing on three groups of inflators (both desiccated and non-desiccated PSPI-L inflators): baseline inflators, inflators with 0.3 percent moisture added, and inflators with 0.6 percent moisture added. Because baseline inflators had 0.07 percent moisture, the total moisture content in the propellant is 0.37 and 0.67 percent. Takata tested the inflators after 200, 500, 1000, 2000, and 4000 cycles. The testing included CT scans (to detect grain growth), 60 liter tank tests, and live dissections.

The non-desiccated inflators had ruptures at 2000 cycles (baseline), 1000 cycles (0.3 percent water) and 200 cycles (0.6 percent water). The desiccated versions, by comparison, resulted in a rupture only at 4000 cycles (baseline). The desiccated versions exhibited substantially less grain growth.

Takata also conducted the same testing on PSPI-X models that use Takata's newer 2004L formulation. Testing was done on baseline inflators (no moisture added). The results showed little to no grain growth and normal ballistics at 4000 cycles.

Overall, the results of Takata's testing shows relative increases in robustness both from the addition of desiccant and the use of Takata's newer 2004L propellant. These differences can be seen by the differences in grain growth between the various combinations, as demonstrated below, where grain growth is increasing along the vertical axis.

The *relative robustness* of cylindrical passenger inflators studied here can be compared by looking at the wafer growth rate:



The use of the 2004L propellant and the addition of desiccant appear to prevent grain growth (represented by the slope of the line), such that no grain growth was observed in the desiccated 2004L propellant after 4000 cycles.

Ultimately, Takata concluded that the latest evidence continues to support the original high absolute humidity root cause theory, and that moisture remains an enabling element for the degradation process, but that temperature exposure is also necessary.[62]

Q. *May 2016: NHTSA and Takata amend the November 3, 2015 Consent Order and Takata files additional DIRs*

On May 4, 2016, Takata and NHTSA agreed to amend the November 3, 2015 Consent Order (the "Amendment"). In the Amendment, NHTSA concluded, based on an independent review of the science by three independent research organizations and in consultation with its expert Harold R. Blomquist, Ph.D., that the likely root cause of the rupturing of most non-desiccated frontal Takata airbag inflators is a function of time, temperature cycling, and environmental moisture. NHTSA concluded that Takata's non-desiccated frontal PSAN inflators do not pose an unreasonable risk to safety until they reach a certain level of propellant degradation, but found that all non-desiccated frontal Takata PSAN inflators will eventually reach a threshold level of degradation that could result in the inflator's becoming unreasonably dangerous. NHTSA's conclusions, and those of Dr. Blomquist, relied in part on analysis conducted by Exponent, Inc., an engineering and scientific consulting company engaged by a vehicle manufacturer to assist in its investigation. Takata has not had an opportunity to review Exponent's analysis or conclusions.

NHTSA estimated that the service life expectancies of these inflators range from 6 to 25 years, depending on environmental exposure. Accordingly, NHTSA directed Takata to issue DIRs on a rolling basis for all non-desiccated frontal PSAN inflators in three different geographic zones. The timing of these DIRs follows the environmental risk of degradation as determined by NHTSA: Older inflators and inflators subject to the environmental conditions of higher temperature fluctuation and humidity are to be recalled first.

In compliance with the Amendment, Takata filed its three initial DIRs on May 16, 2016.[63] The filing of these DIRs by Takata in accordance with the Amendment led the vehicle manufacturers to recall vehicles equipped with the covered inflators. These recalls will become part of NHTSA's Coordinated Remedy Program, and will be subject to the prioritization schedules established by that program. It is expected that in prioritizing vehicles for replacement parts, the Coordinated Remedy Program will also consider the significant differences in expected inflator service life in different vehicle makes, models, and vehicle platforms.

Finally, the Amendment relieved Takata of its obligation to continue testing non-desiccated frontal PSAN inflators, but required that Takata shift, as soon as possible, to testing desiccated PSAN inflators. Takata is preparing a plan for such testing.

As previously stated, NHTSA's conclusion regarding the root cause of Takata inflator ruptures was based, in part, on the conclusion of its expert Dr. Blomquist. Dr. Blomquist's expert report, which was attached to the May 4, 2016 Amendment, stated that he agreed with the general consensus that had been developed previously regarding root cause. Specifically, Dr. Blomquist found that:

- Affected inflators are inadequately sealed, which permits moisture intrusion;

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[62] With regard to the SDI inflator, which uses propellant tablets rather than wafer-shaped propellant, investigation is ongoing to identify the potential effects of high humidity and heat on the tablets, including the rate of moisture ingress and the process and rate of change upon the mechanics and crystallinity of the propellant, as well as the potential influences of manufacturing variability upon the potential for inflator rupture.

[63] DIR Nos. 16E-042, 16E-043, and 16E-044.

- This moisture causes the formation of pores and channels in the propellant;
- Over the course of years, the extent of this degradation progresses by a slow process driven by temperature fluctuations;
- During combustion, hot gas enters the pores and channels in the propellant, causing a transition from layer-by-layer burning to an *en masse* burning that causes over pressurization and inflator rupture.

Based on the evidence reviewed, Dr. Blomquist found that the amount of time needed before a risk of inflator rupture develops depends on environmental factors, but stated that it ranged from approximately 6 years for inflators in high humidity and high solar load environments, to 25 years for regions with lower humidity and lower solar loads. As noted, Dr. Blomquist's opinion is based, in part, on his understanding of the analysis done by Exponent, which has not been shared with Takata.

XV. Remedial Steps Taken by Takata to Enhance Safety Process

In cooperation with NHTSA and in consultation with numerous independent experts, Takata has taken several significant steps to ensure that the safety lapses and product failures that have occurred do not occur again.

A. *Independent Monitor*

In response to data integrity and reporting issues and other matters disclosed to NHTSA by Takata in the course of this investigation, and pursuant to the November 3, 2015 Consent Order, NHTSA appointed John D. Buretta, a partner at the law firm Cravath, Swaine & Moore LLP and a former career federal prosecutor and Department of Justice official, as the Independent Monitor for Takata. The Independent Monitor will oversee Takata's safety and compliance programs and other obligations under the Consent Orders. This includes reviewing Takata's compliance with the phasing out of PSAN inflators, internal Takata safety improvements, Takata's compliance with its "Get the Word Out" digital outreach plan, and Takata's compliance with its plan to provide NHTSA with test data and other information regarding service life and safety of replacement inflators. The Monitor is also tasked with receiving any reports of violations of law or unethical conduct at Takata. The Monitor may conduct an investigation and/or refer any reported matter to NHTSA and/or the Department of Justice.

B. *Safety hotline to Independent Monitor*

Takata has established a Safety Hotline that any Takata employee can call and speak directly to the Independent Monitor. Employees may also file anonymous reports at http://www.takatamonitor.org/.

C. *Chief Safety Assurance and Accountability Officer*

In December 2015, and in accordance with the November 2015 Consent Order, Takata appointed Eric Laptook as Chief Safety Assurance and Accountability Officer ("CSO"). Mr. Laptook also serves as Takata's General Counsel and Chief Compliance Officer. As CSO, Mr. Laptook serves as the primary point of contact and coordination with the Independent Monitor and, along with assigned staff, monitors Takata's compliance with the Consent Orders and the Coordinated Remedy Program Order of NHTSA.

Prior to joining Takata, Mr. Laptook was a member of the Legal Division of the North American subsidiary of a large Japanese trading company, serving for nine years as Senior Vice President, General Counsel and Chief Compliance Officer. During his tenure with his previous company, he played a major role in many significant transactions in a wide range of business areas, managed significant litigation and investigations, and created a compliance program that served as the model for the global organization. His knowledge and experience with corporate governance has made him a valuable contributor to the many corporate boards on which he has served as a director or advised as counsel.

Takata has also established and is staffing a Safety Accountability and Assurance Office ("SAAO"), which reports to the CSO.

D. *Employee terminations*

In accordance with Paragraphs 33.b and 52 of the November 3, 2015 Consent Order, Takata gave notice to NHTSA on December 31, 2015 that Takata and TKC had terminated the employment of several individuals in relation to the subject matter of the Consent Order.

E. *Data vault*

Takata is in the process of enhancing its data vault—created in 2010—which archives data, including testing data, and ensures that such data is written and cannot be changed during a retention period of 30 years. Takata has engaged an independent national auditing firm to perform an examination of Takata's data vault. Takata also is continuing to evaluate additional measures to ensure the security and preservation of its data.

F. *Internal compliance and regulation posting system*

Takata has updated its intranet to provide employees with a venue to report issues with, or ask questions regarding, Compliance and Regulations Guidelines.

G. *Establishing an enterprise-wide Product Safety Group*

In 2014, Takata established an enterprise-wide Product Safety Group tasked with authority to address potential safety-related issues for all Takata products. The group educates and informs Executive Management, governmental authorities, regulatory agencies and Takata's customers of its findings. The group has the authority to sponsor corrective actions and, if necessary, to conduct and manage appropriate field actions.

The Product Safety Group is in charge of investigating pre- and post-launch safety issues identified in any Takata products. It directs root cause investigations, oversees countermeasures, and has authority to stop production and quarantine parts based on its findings.

The Group also manages governmental requests for information and recalls. The group has full access to all engineering, quality, and production records and data.

The Product Safety Group and the SAAO are also tasked with preventing safety issues that may require recalls by:

- Auditing Design Failure Mode and Effect Analyses ("DFMEAs") and Process Failure Mode and Effect Analyses ("PFMEAs") to insure they are appropriately conducted
- Analyzing Non-Conforming-Material Reports, Deviations, LAT Data, and Conformance of Production evaluations to look for potential quality concerns
- Establishing product surveillance strategies

- Analyzing vehicle manufacturer warranty information and NHTSA's Vehicle-Owners Questionnaire database for early warning indicators of potential issues
- Auditing design reviews
- Auditing production samples to ensure quality compliance

Takata will establish a Product Safety Compliance Committee ("PSCC"). The PSCC will be responsible for overseeing and ensuring resolution of all potential compliance issues. The PSCC will be independent and report to the Product Safety Compliance Board ("PSCB"), which will be responsible for making the final decisions regarding the disposition of all product safety compliance issues. Any recall decision requires review by the Executive Board of TKC.

H. *Daily quality meetings*

Takata has established a daily meeting system and new escalation processes such that Takata's manufacturing facilities will report concerns within 24 hours to the relevant Quality Assurance personnel. The relevant Quality Assurance personnel will then review these concerns and, if necessary, the concerns will be routed for distribution in the Early Warning System, described below. The Quality Assurance personnel will also escalate any critical issues (those which pertain to loss of function, occupant safety, or government compliance) to the Special Task Force, which will review the issue in detail. The Special Task Force comprises representatives from Quality Assurance, Sales, Engineering, and Manufacturing. The applicable regional Quality Assurance Vice President will notify the Global Quality Assurance Vice President, Product Safety Group, and the Chief Operating Officer of the Special Task Force findings.

I. *Early warning system*

Takata has established an Early Warning System that will notify all potentially affected manufacturing plants about a potential risk of a quality incident in order to enable them to take appropriate action. Upon receiving an Early Warning, every plant is required to acknowledge the receipt and state potential risks based on available information within 24 hours.

J. *Global horizontal deployment system*

Takata has required that a Global Horizontal Deployment Form be filled out by employees whenever a quality incident occurs at a Takata manufacturing facility. The form is designed to describe the nature of the incident, the root cause, and the countermeasures taken. The form is to be distributed to various managers throughout Takata, who must confirm implementation of the same countermeasures or confirm that measures already in place prevent the occurrence of the issue.

K. *Third-party audit of inflator validation reports*

Takata and a vehicle manufacturer have jointly commissioned an audit of certain of Takata's validation testing reports. The audit is designed to identify any anomalies in the reporting of test results that could potentially indicate significant safety risks related to inflators supplied to the vehicle manufacturer by Takata. The Auditor is Brian O'Neill, former president of the Insurance Institute for Highway Safety, and he is assisted by Douglas P. Campbell, a former inflator engineer and current president of the Automotive Safety Council, and by data analysis experts.

L. *Independent review of non-AN propellant and inflators under development*

Takata has requested Fraunhofer to conduct an independent review of non-AN propellant and inflator products that Takata is developing for use as replacement kit inflators and in new production offerings.

M. *Independent Takata Quality Assurance Panel*

In December 2014, Takata established an independent Quality Assurance Panel, comprising seven leading experts in various areas such as transportation safety, manufacturing, quality assurance, engineering, Japanese business, and government regulation. The Panel was tasked with reviewing and assessing Takata's current policies, practices, procedures, structure and personnel to ensure that Takata achieves best practices for:

- Expeditious, accurate and thorough internal and external reporting of questions or concerns about the quality or safety of Takata airbags
- Development and implementation of action plans to fully, promptly and conscientiously resolve any such questions or concerns
- Integration of quality and safety principles at every step in Takata's supply, manufacturing and delivery channels
- Global coordination of all aspects of Takata's management of airbag quality and safety issues

The Panel was led by former Secretary of Transportation Samuel Skinner. A former U.S. attorney, Secretary Skinner has had a career in both the public and private sectors. Secretary Skinner acted as the president's point person in numerous crisis situations, including the 1988 terrorist bombing of Pan Am flight 103 over Lockerbie, Scotland, the Eastern Airlines strike, the Exxon Valdez oil spill, the northern California earthquake, Hurricane Hugo and the 1991 national rail strike. Secretary Skinner is the retired chairman, president and chief executive officer of USF Corporation, one of the nation's leading transportation and logistics companies. The six other members of the Panel bring decades of experience and leadership in transportation and safety issues in industry, academia, and government, as well as extensive expertise in engineering, medical science, and business management. The members of the Panel do not have commercial or financial ties to Takata.

The Panel issued its report in February 2016. The report represents the independent review, analysis, and conclusions of the Panel. A full copy of the report is available at: http://www.takatapanel.com/panel-report/. The report made 15 recommendations, all of which Takata has undertaken to implement:

- Refine the approach to monitoring in-fleet product performance.
- Ensure quality and safety concerns can stop product development.
- Ensure that data from quality performance testing is recorded and reported accurately.
- Develop a Takata standard for product safety specifications.
- Adopt a standard practice for seeking and utilizing third-party review.
- Increase and standardize automation operations across facilities.

- Reduce the incidence of conditional approvals in the design review process.
- Involve manufacturing earlier in the product design process.
- Ensure the design review process is outcome driven.
- Establish lifetime ownership over Takata product programs.
- Increase consistency in monitoring and documenting critical specifications and processes.
- Cultivate a quality culture at Takata.
- Increase leadership support for and involvement in quality initiatives.
- Link quality performance and compensation at the individual level.
- Guarantee sufficient resources are available in quality critical areas.

The Panel also had four recommendations to facilitate implementation of the Panel's recommendations:

- Create a dedicated quality team to supervise the implementation of the Panel's recommendations.
- Develop a detailed plan to implement the Panel's recommended changes that includes metrics of success.
- Develop a reliable and robust monitoring program.
- Develop a comprehensive quality training program.

Takata intends to put into place all of the Panel's recommendations, in addition to the other systemic policy and practice improvements previously detailed. The Panel and Takata have agreed that Takata will provide the Panel with a report one year after the Report's issuance, in which Takata will summarize its progress in implementing the Panel's recommendations. Takata also continues to report on compliance with its obligations under the NHTSA Consent Order on a regular basis.

XVI. Conclusion

Takata's mission is to make products that save lives and prevent serious injuries, and its chief concern is the safety of the driving public and the safety of its products in the field. Takata deeply regrets the deaths and injuries that have occurred as a result of the failure of its products to perform properly, and extends its sincerest apologies and condolences to those victims and their loved ones. Takata also deeply regrets the instances in its history where the integrity of its testing data and reporting has been compromised, and the company is committed to ensuring that no such lapses ever recur. Takata is dedicated to working with Congress, NHTSA, the Independent Monitor, vehicle manufacturers, independent experts, and regulators around the world to address the issues giving rise to this report. Takata continues to increase its efforts to improve production quality, to test products safely and accurately, and to support appropriate recalls of vehicles on the road.

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August 31, 2016

BY EMAIL

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Re: Corrections to the Report of TK Holdings Inc. Pursuant to Paragraph 33.a of the November 3, 2015 Consent Order in EA15-001

Dear Beth:

I am writing on behalf of TK Holdings Inc. ("Takata") to advise the National Highway Traffic Safety Administration ("NHTSA") of two minor corrections to the June 30, 2016 report of Takata submitted to NHTSA pursuant to Paragraph 33.a. of the November 3, 2015 Consent Order.

First, as Takata previously informed NHTSA on August 16, 2016, on page 14 (in section IV.B), the report should state that Takata changed the maximum moisture level for 2004 batwings from 0.20 wt. percent to 0.12 wt. percent in ***September 2010***, not 2007. Second, on pages 5 and 60 (in sections II.G and XIII.A), the report should state that ***three*** Japanese vehicle manufacturers, not two, initiated recalls in 2010 in response to ruptures in SPI inflators that occurred during inflator disposal in scrapyards in Japan in 2009 and 2010.

We ask that these two corrections be deemed part of the June 30 report. Please let me know if you have any questions.

Best regards,

Steven G. Bradbury