NIATT

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# Technovations in Transportation

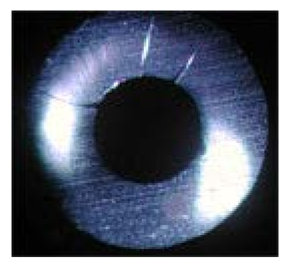
**In this issue:**



## Thermal Stresses in Pyrotechnic Initiators-- The Effect on Airbag Safety

It is no secret that airbags save lives: Over 15,000 lives, in fact, airbags were first installed in the Oldsmobile Toronado in 1972. Airbags, also known as Supplemental Restraint Systems, are flexible, rapidly-inflating envelopes that are used for cushioning when the vehicle in which they are installed is involved in a collision. Deployment occurs when crash sensors on the front and sides of a vehicle are activated, sending a signal to the airbag's inflator--the device which generates the gas required to inflate the airbag cushion.

The inflator contains a small electro-explosive device sealed within a glass and metal enclosure. This pyrotechnic initiator is responsible for starting the gas-generating chemical reactions within the inflator. During a collision, an electric current within the inflator heats the bridgewire (often made from a platinum alloy), which in turn, ignites pyrotechnic (combustible) material. This electro-explosion heats stored gases, or actuates flow control mechanisms, which cause the airbag to inflate.



Successful airbag deployment depends on these pyrotechnic initiators, which are roughly the size of a thumbnail. If the initiator and airbag are functioning properly, gas begins to flow into the airbag about 1 millisecond after the collision is detected. Depending on the type of airbag, the cushion is fully deployed between 10 and 40 milliseconds later. photograph of cracks in pyrotechnic initiator

Automobile owners expect that airbags, unless deployed, will remain fully-operational for the life of their vehicles. However, defects, such as cracks in the insulating glass could potentially allow moisture to penetrate the device, possibly corroding the critically important internal electrical components or leading to degradation the pyrotechnic material, thereby resulting in improper operation of the device. Cracks and other flaws have been detected in some units (see photograph to right), and it is suspected that the source of some of these flaws may be thermal stresses incurred during manufacturing.

Dr. Karl Rink, associate professor of Mechanical Engineering at the University of Idaho, along with graduate students Dan Gunter, Andrew DuBuisson, Mike Klein, Luke Thompson, Chris Fischer, and Mike Maughan, set out to determine when cracks occur during the manufacturing process and to compare these results to cracks observed in pyrotechnic initiators currently in use. They have also used advanced test methodologies and analysis to predict how quickly debilitating moisture may penetrate into an initiator. In addition, they have developed a unique laboratory where they can measure the degradation in performance caused by the presence of moisture within initiators.

## Analysis of Thermal Stresses

Dr. Rink, along with colleagues Dr. Don Blackketter and Dr. Robert Stephens, analyzed two methods that can be used to manufacture initiators. In one method, components are assembled at room temperature. The initiator is then heated in a furnace until the glass melts to produce a seal and cooled back to room temperature. In the second method, not directly applicable to current production methods, molten glass is used to form the seal.

- Using computer analytical programs to solve mathematical models, the research team evaluated the affect of a wide range of temperatures on the initiator during its manufacture, studying how thermal stress affects glass strength. They determined that if the initiator is uniformly cooled (both on the surface and in the interior), tensile stresses, but not cracks, may occur. These findings agreed with photographic evidence obtained through study of actual initiators.

## Evaluating the Propensity for Leaks in Pyrotechnic Initiators

To ensure moisture won't penetrate these devices, manufacturers use tracer gas leak detection methods in an attempt to verify their hermetic integrity. A complication with these methods is that there is essentially no internal volume available for the introduction and accumulation of tracer gases within an initiator. Dr. Rink and his research team sought to expand knowledge of this under-appreciated effect using a krypton-85 radioisotope containing gas as a tracer. Using a special machine called a Radiflo® leak detection apparatus, they recorded the rate of flow of krypton-85 from specially-prepared, small cavity devices with volumes similar in size to those found in pyrotechnic initiators. Their experimental results compared favorably with well-established fluid flow models and provided further confirmation as to why cracks in the glass seals of initiators are occasionally found to escape detection by conventional methods.

> [Accurate leak testing] is important for the industry to ensure the reliability of [airbag initiators]. Karl Rink is one of the few people who have studied these effects and have published their results. [Because of Rink's work] there is now movement to change the relevant military standards to a more reliable method of performing the measurements.
>
> Barry T Neyer, Ph.D.
>
> US Military Aerospace Engineering Leader
>
> PerkinElmer Optoelectronics

## Continuing Research

Dr. Rink's work with pyrotechnic initiators is of interest to more than those in the automotive industry. The United States military and aerospace manufacturers also use these devices for ejection seats and pin-pullers, for example. Because of their importance, Dr. Rink and research team are seeking to further characterize where and why the insulating glass cracks; to determine how quickly moisture may enter these devices and how long it takes before the moisture causes the devices to fail; and, ultimately, to develop an engineering basis for leak rate specifications for pyrotechnic initiators.

**Dr. Karl Rink** received his BS in Aerospace Engineering and Mechanics from the University of Minnesota in 1983 and his MS from Purdue University in 1986. Rink was named an Outstanding Mechanical Engineer by Purdue University in the year 2000. After several years working as a senior design engineer at Solar Turbines Incorporated, Rink returned to academia and earned his PhD in Mechanical Engineering in 1994 from the University of Utah, specializing in the thermal remediation of hazardous materials.

Subsequently, Rink worked for Autoliv, where he was responsible for the development of innovative gaseous, liquid and hybrid airbag inflation technologies. His work in airbag technology led to 50 U.S. patents, one of which earned his employer the internationally-recognized 2000 PACE award.

Rink remains active in a number of technical societies including the Combustion Institute, the American Society of Mechanical Engineers (ASME), and the American Institute of Aeronautics and Astronautics (AIAA), for which he serves as Vice-Chair of the Technical Committee on Energetic Systems and Components.

In his spare time, Karl enjoys playing and coaching hockey (some of his original teeth remain intact) and riding horses with his wife Linda.

**Chris Fischer** (right) received his BS in mechanicalChris Fischer working with the Radiflo engineering at the University of Idaho in 2002. Following graduation, he worked at Autoliv ASP, the worlds leading manufacturer of automotive airbags. Chris returned to UI in the fall of 2005 to work towards his MS under the guidance of Dr. Karl Rink. Chris comes from Twin Falls, ID.

**Dan Gunter** (MSME '02) lives in Redondo Beach, California and works for The Aerospace Corporation where he performs analytical work on launch vehicle ordnance systems. Dan grew up in Park City, Utah, and likes to spend his free time skiing, snowboarding, running, biking, cooking, traveling, or reading.

**Andrew DuBuisson** (MSME '02) currently works for Freeman Marine Equipment in Gold Beach, Oregon, as a contract design engineer. Andrew grew up in Coeur d'Alene, Idaho, and enjoys playing ultimate Frisbee.

**Michael Klein** (MSME '02) works as a design and stress analyst on Boeing's 787 airplane's landing gear. Between graduation and accepting his job at Boeing, Mike spent 7 months in New Zealand on a work-abroad program and in Boise, Idaho, where he helped the UI Boise campus outfit their engineering machine shop. Since moving to Seattle, he has taken up mountaineering and has had great opportunities to experience the inclement weather of the Cascades as well as some grand vistas of their summits.

**Publications**

Rink, K. K., **"Fundamental Considerations Concerning the Detection of Gross Leaks in Bridge-Wire Initiators,"** International Journal of Vehicle Safety Vol. 1, No. 4, pp. 253-266, 2006.

Rink, K. K., "Failure Mode Investigations Related to Non-Hermetic Behavior in Bridge Wire Initiators," proceedings of the 5th Cartridge-Propellant Actuated Device Technical Exchange Workshop, Naval Surface Warfare Center, Indian Head, Maryland, 2004.

Thompson, L. M., Thermal Stresses in Airbag Initiators, MS Thesis, University of Idaho, 2005.

This research is essential to establish more stringent quality control for potentially life-saving applications. By identifying leak paths and quantifying leak rates, we can more consistently be able to remove ineffective initiators from the market and more effectively determine the life of an initiator ensuring reliable deployment of airbags.

Michael K. Klein, MS '02

Rink, K., Failure Mode Investigation and Ballistic Performance Characterization of Pyrotechnic Initiators Used in Automotive Supplemental Restraint Inflation Systems, NIATT Report **N06-04**.

Rink, K., Thermal Stresses in Pyrotechnic Initiators Used in Automotive Supplemental Restrain Systems, NIATT Report **N06-05**.

**Funding**

Funding for this project came from the US Department of Transportation Research and Innovative Technology Administration Grant No. DTRS98-G-0027.

## ITE Student Chapter Brings Traffic Bowl Trophy Home

Engineering students won top honors at the Traffic Bowl last month, beating out teams from Washington, Portland and Oregon State Universities and the University of Oregon. The annual Traffic Bowl is a Jeopardy-style competition organized by the Northwest section of the Institute of Transportation Engineers (ITE). ITE Student Chapter captures first Place in Traffic Bowl

The students, members of the ITE student chapter and undergraduate civil engineers, took home a trophy and cash prize. Competing were Dennis Ownbey, Kimberly Baird, and Nicholas Taylor, chapter president (shown in photo, left to right, with Chris Teisler of Kittelson & Associates, a sponsor of the competition).

All three UI contestants contributed to the win. UI took the lead first when Nick Taylor, president of the chapter, correctly answered several questions about the "Green Book," the AASHTO highway design manual. Dennis Ownbey has worked with Dr. Michael Dixon, chapter advisor, on roundabouts, so he was able to help the team keep the lead by correctly answering most of the questions in the round that focused on roundabouts. Freshman Baird answered a question about colors of highway striping. The team held their lead with strategic betting in the final round in which no team had the correct question to the answer, "The 13 states through which I-90 passes, east to west or west to east."

The student chapter meets regularly and will begin planning their annual field trip, where they meet with transportation professionals and take several tours. Past trips have been to Washington, DC, Las Vegas, and Portland.

"University of Idaho engineering students' performance in the traffic bowl is a great example of how our transportation engineering students stack up against students from other universities throughout the Northwest," said Dean Aicha Elshabini.

ITE is a professional society of transportation engineers, planners and other professionals in more than 70 countries. The goal of the Idaho student chapter is to introduce students to the transportation profession and supplement their classroom and laboratory experiences.

## Apply now for Traffic Signal Summer Workshop VII

The traffic signal is one of the most important devices in the nation's transportation system. In January 2004, FHWA proposed a multiyear roadmap for a new traffic signal timing program that is designed to reduce congestion and improve flow and safety by providing dramatic and sustained improvements in traffic signal operations throughout the US.

> The workshop was extremely useful in learning the concepts of traffic signal design, timing, controller operation, and detection. The hands-on environment is truly unique and provides an excellent method of teaching all aspects of traffic signals. I would recommend this course to any student with an interest in traffic signals.
>
> Gene McHale, FHWA

NIATT's Traffic Signal Summer Workshop offers hands-on-training for future transportation engineers in the operations of traffic signal systems. This training has already been experienced by 72 participants from 33 universities, DOTs and FHWA. You, too, can prepare yourself to gain the skills and competencies needed to prepare yourself for a career in transportation engineering.

Spend one week on the University of Idaho campus (August 5-10, 2007) working with industry professionals, using the latest traffic signal systems equipment and software. Applications are being accepted until June 4, 2007.


Apply now for one of the 12 spots open.

## Research at NIATT

Given the increased complexity of surface transportation systems--and increasing physical and electronic threats against those systems--it is imperative that an Intelligent Transportation System be designed not only for safety and efficiency, but also for survivability. A team of researchers at NIATT led by Drs. Paul Oman, Ahmed-Abdel-Rahim, and Brian Johnson, successfully modeled the criticality of traffic system components in a small urban ITS system (Moscow, ID), and a large metropolitan area (Boise, ID). This work followed an initial study that used a Security/Survivability Systems (S/SSA) to formalize "softspot" analysis of traffic/transportation control networks, including identifying essential services and intrusion scenarios.

Abdel-Rahim will present a paper resulting from this work, "Survivability Analysis of Large-Scale Intelligent Transportation System Network," at the 86th Annual Transportation Research Board Meeting in Washington, DC. This research was funded in part by the US Department of Transportation Research and Innovative Technology Administration Grant No. DTRS98-G-0027.

The research team's **current project** involves defining and developing a computational framework to identify and prioritize critical components in surface transportation networks to allow engineers, management and emergency planners to allocate funds to improve the survivability of a system.

Use the **research database** on NIATT's website to read our most recent research reports. Among them is the final report for the University Transportation Centers Grant-supported project, **"Applying Safety-Critical Fault Tolerant Principles to Survivable Transportation Control Networks,"** authored by Paul Oman and Axel Krings.

## Transportation Fellowships Available for Fall 2007

A select number of students who wish to pursue MS degrees in transportation engineering at the University of Idaho will receive fellowships for the 2007-2008 academic year.

Recipients will receive a stipend of $27,500 for the year (with all student fees also paid) to work on challenging transportation problems with top researchers.

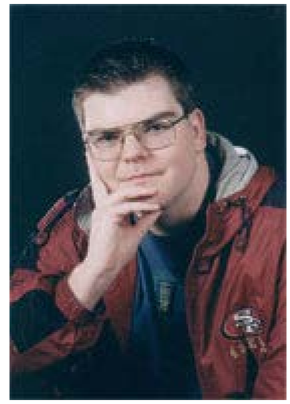
Earn your MS degree in a field offering ever-increasing job opportunities in both the private and public sector.

Applications, available online, are due no later than May 1, 2007.

## Congratulations to the 2007 NIATT Student-of-the-Year!

## Matt Benke Shares Some Thoughts

Between Dr. Oman, Dr. Abdel-Rahim, Dr. Johnson and the many great students with whom I had the privilege of working at NIATT, I couldn't have hand-picked a better group. The professors are not only experts in their chosen fields, but were the perfect fit for me personally. Someone had to keep me focused and out of trouble, and provide some wisdom from personal experience that every graduate student needs . . .To this end they provided more than I ever could have asked.



Matthew BenkeThe professors represent three disciplines--computer science, civil engineering, and electrical engineering--at the highest level. They contributed a variety of perspectives to our research, and it was this interaction among various backgrounds that led to our most significant achievement in transportation survivability research: multilayered analysis that considers interaction among components in multiple infrastructures--communications, power, and transportation--on common ground in simple terms based on service to users. Thankfully, their diverse backgrounds rubbed off a little on me. I was happy to contribute to NIATT with my computer security knowledge, and pick up some pointers in power and transportation along the way!

When you think about it, though, this is a microcosm of the future of transportation. Transportation systems, while traditionally a matter for civil engineers, continue to incorporate knowledge from a wide variety of disciplines, from recognized backgrounds like mechanical and materials engineering, to the aforementioned computer science and electrical engineering, to even more exotic disciplines like economics, psychology, and law. Mechanical and materials engineers will continue to play a prominent role by developing vehicle designs that become increasingly less reliant on gasoline and incorporate renewable resources.

Computer scientists will contribute to the secure communications networks that will become ever more prolific in future transportation systems as it evolves into a system based on user- and vehicle-infrastructure integration, and to the secure embedded systems design that is necessary for vehicles to safely incorporate more advanced, even automated, technologies. Electrical engineers will continue to improve electric and hybrid vehicle design and provide improved energy service to the transportation infrastructure. Economists will contribute ideas for how the vehicular communications infrastructure can be utilized in electronic tolling systems and commercial endeavors, and even in the development of a vehicle-infrastructure information economy. Psychologists will continue to improve human-vehicle interaction and research the role of trust as more automated transportation technologies are introduced, taking much of the control away from drivers. (Notice I'm not justifying law...this is already taking too long.) And civil engineers will play as crucial a role as ever, as they develop safe roads and structures that can not only sustain increased traffic, but the infrastructural mechanisms alongside (and perhaps even embedded in) the roads to support communications among that traffic.

When Dr. Abdel-Rahim told me eight months after I graduated that I had been named NIATT Student-of-the-year, I thought it necessary to remind him that not only was I no longer a NIATT student, but I was not even a NIATT student at any point during 2006! When he explained that overall multidisciplinary contributions over the last two years were considered for the award, I finally understood. I am humbled to even be considered among those students that continue to make amazing contributions to transportation safety, sustainable transportation, smart pedestrian signals, human-vehicle interaction . . . the list goes on. But advanced transportation is a truly multidisciplinary endeavor, and its continued success relies on the enormous diversity of its contributors. In accepting the award on behalf of all the other students in these various disciplines with whom I worked, I'm proud to represent the potential that computer science brings to the transportation industry, and hope people of all backgrounds see copious opportunities to contribute their own unique ideas.

Matt received his MS in computer science in 2005. Read more about Matt and past students-of-the-year

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