



# AXPRO NEWSLETTER

ISSUE 3: AUGUST 2016

This past semester, Dr. Petr and his Advanced Explosives Processing Research Group (AXPRO) continued advancing their research and education activities at the Colorado School of Mines, are very excited to be developing their explosives engineering program for graduate students, expanding research and continuing education into ultra high-speed imaging, and researching initiation systems and explosives characterization.

## Education

This spring, AXPRO began a collaboration with the Missouri University of Science and Technology (MS&T), in the form of offering a long distance learning course on the special use of explosives. Graduate students at MS&T visited the Explosives Research Laboratory (ERL) during Spring Break, and experienced practical work with explosives, including: explosives welding, explosives engraving and forming, and avalanche control operations. One day was spent with the CDOT Avalanche Control Team, outside the Eisenhower Tunnel, near Empire, Colorado. In addition, students learned about various other industry and military applications for explosives, receiving lectures on explosives use in fields such as aerospace, agriculture, oil and gas, and etc.



Figure 1. Students experienced practical work with Explosives at the ERL in Idaho Springs, Colorado.



Figure 2. The CDOT Avalanche Control Team showed the MS&T students some of the technology that is used to mitigate avalanches in Colorado.



Figure 3. Students worked together to assemble a detonating cord matrix.

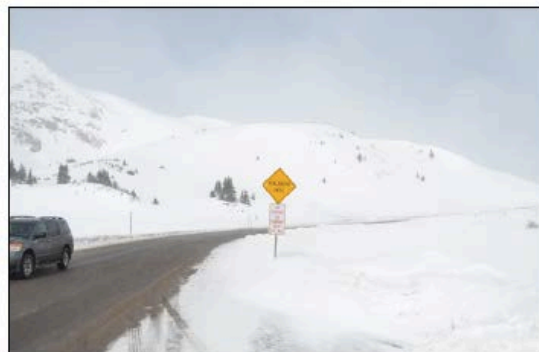


Figure 4. Students were able to visit an avalanche area in Loveland Pass, Colorado with the Colorado Department of Transportation.

The AXPRO team spent part of the summer preparing for and teaching a series of Avalanche Training courses in collaboration with the Colorado Department of Transportation (CDOT). AXPRO typically offers a more general two-day training session on avalanche control with explosives, and then gives students the opportunity to learn about specific operations in CDOT avalanche control with four more practical eight-hour courses: Hand Charge Training, Rock Fragmentation Training, Case Charge Training, and Unexploded Ordnance Training.

While the Hand Charge and Rock Fragmentation Training courses are regularly offered each year, this is the first time that AXPRO is teaching a course about the manufacturing/implementation of Case Charges. The AXPRO team recently improved upon the design of CDOT Case Charges, enhancing their effectiveness in avalanche mitigation, and is excited to be introducing this training course. Students will learn the proper safety procedures for Case Charge operations, how to correctly manufacture Case Charges, and effective Case Charge emplacement for improved results.

The Unexploded Ordnance Training course (dealing with CDOT practices and operations for misfires and DUDs) was offered in previous years, but AXPRO has since updated it and is reintroducing it this August. In this course, students will be learning about the CDOT safety procedures and techniques that must be followed when an explosive device does not operate or detonate as expected. CDOT students will also be expected to learn how to assemble (with a matrix tool) and effectively use matrices, unique tools that are often used by law enforcement officials to disrupt an explosive device.



Figure 5. CDOT students drill into a rock during the Rock Fragmentation Training Course at the ERL.

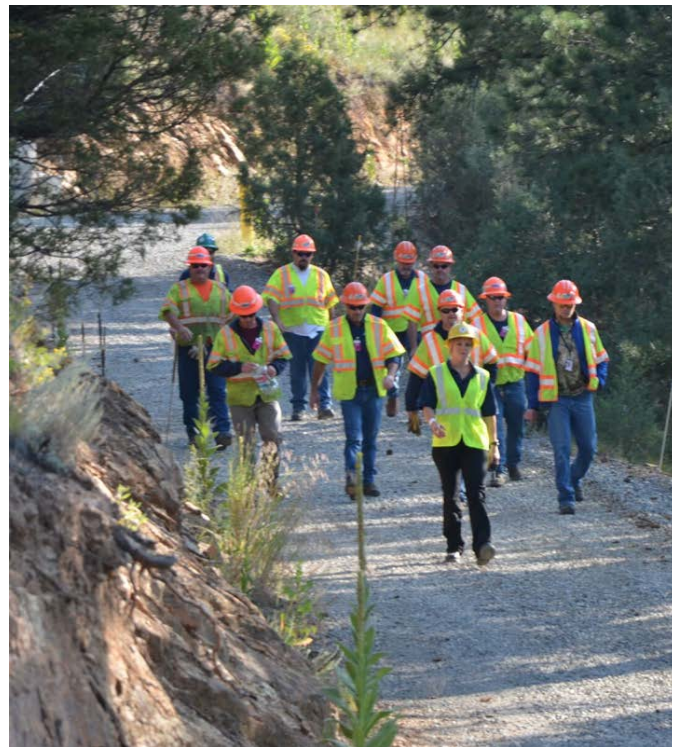


Figure 6. CDOT students walk the perimeter of the ERL during safety training.

AXPRO is currently developing an Explosives 101 course in collaboration with the Jefferson County Sheriff's Department. Mark Gutke, Bomb Squad Commander, and John Lipka, a former FBI Special Agent, are both working with the AXPRO team to design the most applicable course. Prospective students must have law enforcement backgrounds, and can expect to gain a familiarization with the explosive materials and compounds that are typically found in their area of responsibility

AXPRO is pleased to be offering two courses on experimentation techniques in explosives engineering this fall: High-Speed Imaging Methods for Research and Experimentation (HSI) and Ultra High-Speed Framing Imaging for Research and Experimentation (UHSI).

A global leader in the manufacturing of high-speed digital cameras, Vision Research, sponsors the HSI course. The goal of HSI is to teach students how to effectively use high-speed imaging for the evaluation of explosive materials and ballistics. Tailored for both inexperienced and experienced students, this course will educate students in establishing best practices for civilian and military applications, and will offer them the opportunity to participate in a professional network of explosives engineering and high-speed imaging experts.

UHSI offers an introduction to ultra high-speed imaging framing, lighting and sense selection, triggering methods, and analysis strategies. Specialized Imaging Inc., a company that has significant expertise in ultra high-speed imagery, sponsors this course. The course is unique in its focus on practical field exercises, and specialized methods of data acquisition for explosives engineers and individuals in other related fields. Mr. Frank Kosel, the president of Specialized Imaging Inc., visited AXPRO this month to assist the team in developing a method for detonator performance characterization using multi-frame laser Schlieren imaging (backlighting).



Figure 7. Students in HSI stand behind camera boxes during a field exercise at the ERL.

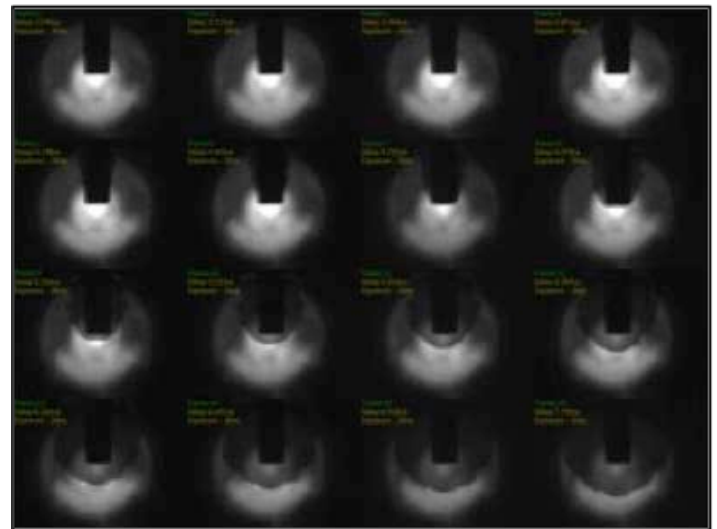
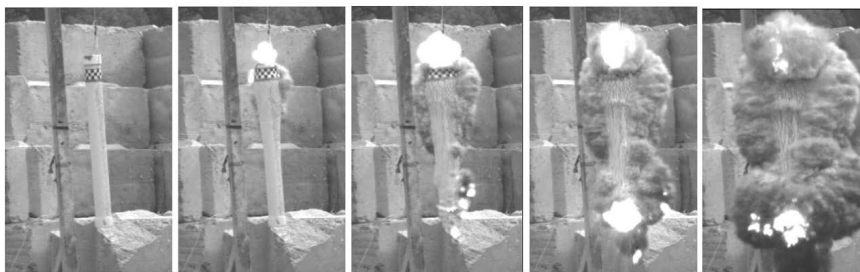


Figure 8. The detonation stages of an EBW RP502; these images were taken during Mr. Kosel's visit, with an ultra-high speed imaging camera, to study the Schlieren effect and overlapping static image.

Figure 9. High-speed images of a detonating case charge.



## Research

The AXPRO team is excited to be commencing a research partnership with CDOT to minimize geological hazards that are encountered during road construction. AXPRO was selected in June to conduct rock-cut perimeter blasting studies. These studies will continue for a duration of 18 months, and AXPRO will be awarded a total of \$95,000. AXPRO will be developing best practices for blasting, designs for aesthetic slope construction with long-term maintenance, and slope-stability improvement methods. The research team is composed of industry experts, including: Matthew DeMarco, a former geotechnical leader for the Federal Highway Administration, Vincent Auriemma, the Deputy Public Works Director and City Engineer for the City of Golden, and Dino Bonaldo II, a Department of the Air Force Director in the 721st Civil Engineering Squadron.

The Colorado School of Mines Chemistry Department and AXPRO worked together this past spring to apply for a contract with the Federal Bureau of Investigation (FBI) Laboratory Division. The scope of work involved the physical, chemical, and detection characterization of improvised explosives. While the Colorado School of Mines was ultimately not awarded the contract, theirs was among the highest three that were considered. The AXPRO team is very grateful for the assistance and knowledge of, Dr. Shubham Vyas, a distinguished professor in the Department of Chemistry, Milton McPeck, the president at CKG, Dan Reagan, the Chief Operating Officer at Reagan Partnership, and John Lipka, a former FBI Special Agent and current Director of Security at Bonanza Creek Energy Inc. The AXPRO team plans to continue research in the field of improvised explosive characterization, and is currently applying for a contract with the Department of Homeland Security to develop a Center of Excellence at the Colorado School of Mines for improvised explosives and explosive devices research.

Dr. Ruth Doherty will be working with the AXPRO team in October to learn about and develop experimental techniques to advance her teaching materials for students at Maryland University, and to assist AXPRO is developing new capabilities related to energetic materials. Dr. Doherty was previously the Program Executive Officer for Counter-IED for Department of Homeland Security Science and Technology Directorate. Dr. Doherty also has over 25 years of experience with the U.S. Navy in the research and development of energetic materials.

## Conferences

The AXPRO team attended two different international events related to energetic materials this past summer: the XIII SEM International Congress in Orlando, Florida; and the 42nd IPS Seminar in Grand Junction, Colorado.

During the XIII SEM International Congress, Eduardo made an oral presentation for the paper "Shadowgraph Optical Technique for Measuring The Shock Hugoniot From Standard Electric Detonators" where the AXPRO team introduced an underdevelopment method for the characterization of the energy released from standard detonators by using retroreflective shadowgraph (Fig 11). This method is showing promising results and allows a better understanding of the initiation strength of the detonators than the classic Trauzl lead block test.

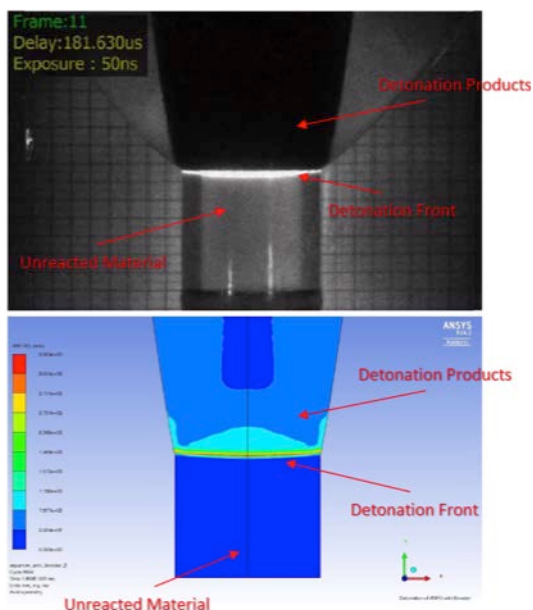


Figure 10. The detonation stages of an EBW RP502; these images were taken during Mr. Kosel's visit, with an ultra-high speed imaging camera, to study the Schlieren effect and overlapping static image.

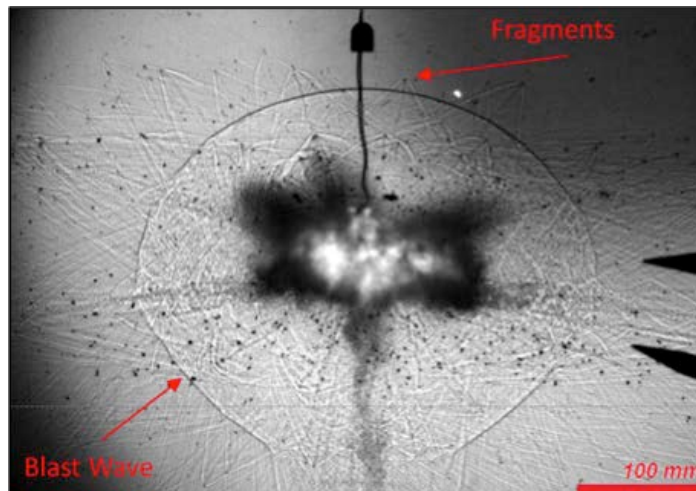


Figure 11. Shadowgraph Frame detonation #6 electric detonator.

The AXPRO team presented their studies related to the detonation process of the widely used Ammonium Nitrate and Fuel Oils (ANFO) in the paper "Characterization of ANFO using Aquarium Test and Numerical Modeling Methods". The ongoing research is showing significant differences in the detonation process of ANFO depending on the prill size for low and high density AN. The aquarium test has proven to be an excellent tool for the characterization of highly non-ideal explosives where the assumptions of the simple detonation theory do not apply. Additionally, a two-dimensional numerical simulation was performed using the hydrocode AUTODYN. Experimental and numerical results show good agreement between JWL equation of state and the high density AN prills. However, the model is not able to represent the detonation front thickness and curvature that is observed from the low density AN prills. The AXPRO team is currently working on these challenges that would provide a better insight to the behavior of non-ideal explosives.

AXPRO will be attending to the ISSW Conference in Breckenridge, Colorado on October 2016. The team will be presenting the paper "Design and Testing of Blast Shield for Avalanche Control used by the Colorado Department of Transportation" in a poster which summarizes the main results of the research and main topic of Eduardo's Master Thesis. In March 2014, an accidental detonation occurred inside a gas gun used by CDOT for avalanche control. CDOT immediately implemented protective measures for its employees. AXPRO at the Colorado School of Mines was selected for the design and testing of a personnel blast shield to mitigate the hazards associated with these operations. CDOT currently owns more than fifteen blast shields that are used by their personnel in every activity involving explosives materials. Future work will be performed by AXPRO in order to validate the fragmentation and shield performance against heavily cased explosive charges.

## Students

Eduardo Lozano recently graduated from the Master of Science in Mining and Earth Resources Engineering on August 2016. Eduardo started his M.S. at the Colorado School of Mines in the Fall of 2015. He worked as a research assistant and teaching assistant for the undergraduate courses explosives engineering I and II and several others explosives short courses imparted at Colorado School of Mines with Dr. Vilem Petr as his advisor. During this time working at AXPRO, he learned a variety of experimental and numerical techniques related to blast and shock that were directly apply to his Master's Thesis: "Design and Analysis of a Personnel Blast Shield for Different Explosives Applications."

Eduardo is starting his Ph.D. degree in Mechanical Engineering at the Colorado School of Mines in August 2016. He was awarded a scholarship that the Society of Explosives Engineers Education Foundation offers annually to students pursuing technical, undergraduate, graduate, or doctorate degrees in fields of education related to the explosives industry. He plans to continue developing expertise in the explosives field while serving as a graduate researcher at AXPRO.



Figure 12. Eduardo during the preparation of a CDOT training class for avalanche control