



Darrell Taulbee shows the damage to a canister base plate after uncoated ammonium nitrate was detonated.

by Jeff Worley

On the morning of April 19, 1995, Timothy McVeigh pulled a yellow Ryder rental truck into a parking area outside the Alfred P. Murrah Federal Building in Oklahoma City then casually walked away. A few minutes later, the truck's deadly 4,000-pound cargo blasted the government building with enough force to shatter one third of the seven-story structure to bits. Glass, concrete, and steel rained down. Indiscriminately mixed in the smoldering rubble were adults and children, alive and dead. Gone in one cataclysmic blast were 168 lives. More than 500 others were wounded. Homegrown terrorism had hit.

The explosive McVeigh used was simple ammonium nitrate (AN), packed in 20 plastic barrels and ignited by a slow-burning fuse. AN is commonly used in agriculture as a high-nitrogen fertilizer, but when mixed with hate and fuel oil, it becomes lethal. The same type of home-brewed fertilizer explosive was used in the 1993 bombing of the World Trade Center by Middle Eastern terrorists.

Preventing another Oklahoma City-like blast is exactly what University of Kentucky scientist Darrell Taulbee aims to do through an ongoing research project to create a fertilizer that, if used by terrorists, won't have nearly the explosive impact of AN. And the idea for this project, says Taulbee, who has worked at the Center for Applied Energy Research (CAER) since 1980, was set into motion by the 1995 bombing.

DEFENDING TERRORISM

“The night of Oklahoma City, I was coming back from a coal ash meeting in Memphis, watching the coverage of this horrible event on TV in the Atlanta airport,” recalls Taulbee, in his deep, mellifluous baritone. “We’d been talking a lot at this meeting about using coal combustion byproducts to alter or remove various materials, so I started thinking about this in connection with defusing the potential explosive power of ammonium nitrate.”

But wait. If AN can be an unwitting participant in a bomb blast, why not just ban its use?

Taulbee, who grew up on a farm 20 miles north of Jackson in Eastern Kentucky, explains that there are two possible alternates to AN, both of which have been used with mixed results. Anhydrous ammonia, a compound formed by combining hydrogen and nitrogen, requires more costly equipment to apply and generates toxic fumes. In addition—and this is no small consideration in Kentucky—the compound, unlike AN, is often used in meth labs.

Another alternative to AN is urea, a white crystalline solid produced when anhydrous ammonia chemically reacts with carbon dioxide, is cost competitive with AN but, like anhydrous ammonia, it is susceptible to costly

volatile loss of its nitrogen and its application must be carefully timed during the growing season. Urea can also be used in the manufacture of explosives though not quite as easily as AN. “Ammonium nitrate is the number one choice of farmers overall,” Taulbee says. “Our central question from the beginning was, can we keep ammonium nitrate from exploding?”

Taulbee’s research, initially funded by the Department of Homeland Security, involves blowing up canisters of ammonium nitrate. His field work is focused on carefully tracking the stages of an explosion.

He explains. “When most people think of an explosion, they think it’s instantaneous, that it happens all at once, but that’s not really true. Explosions happen in stages, or thresholds, one millisecond to the next. Our goal is to drop the energy level so that the explosion won’t self-propagate—it will lose its potency. Basically, we want to decrease the energy flux in this chain so that the explosion will extinguish.”

Taulbee thought that what might stop this chain reaction is the application of an energy-absorbing, fire-impeding coating to the ammonium nitrate. So he set to work.

Taulbee started with the simplest possible solution, using Kentucky’s plentiful supply of byproducts from power plants and other coal-burning utilities, which include fly ash and a lime-based residue produced during the removal of sulfur gases. The coating technique he used is called drum pelletization. Ammonium nitrate particles are put in a five-gallon, steel drum on a roller mill. Cold fly ash is sprayed with a small amount of water, and the drum is rolled rapidly for about five minutes. This gives AN a uniform coating.

To see if this process would lessen the impact of an explosion, Taulbee took this idea to the field or, to put it another way, he took his research back home. “I still have the family farm in Breathitt County, and I also lease about 2,000 acres nearby, which includes an old abandoned log yard. That’s where we did most of our tests.”



Ammonium nitrate (AN) with a 20 percent coating (top) and uncoated AN (bottom) 10 milliseconds after detonation. Darrell Taulbee found that even a 15 percent coating of fly ash halts the explosion.

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Working with Tom Thurman, a retired FBI licensed explosions expert and current instructor in Eastern Kentucky University’s College of Law Enforcement, Taulbee added fuel oil to 10-pound charges of AN that had been coated with different concentrations of ash and placed each charge into a steel canister. Thurman then detonated the cylinders with plastic explosives. A high-speed camera recorded the results, and Taulbee was then able to chart the relative effectiveness of the various densities of coating by charting the expansion of the resulting explosion cloud for 10 milliseconds after detonation.

“We wanted to see two things: the difference between the coated samples and the uncoated, and the relative impact of the coating thickness.” Even at a 15 percent coating, the explosion was halted. Predictably, the thicker the coating, the shorter the distance the explosion traveled.

To determine the impact of each blast, Taulbee also noted the relative damage to the cylinder and its square support stand, called a witness plate, which is welded onto the bottom of each cylinder. In his lab in the basement of CAER, he lifts one of these detonated cylinders.

“You can see that the witness plate has been deformed and that the top of the cylinder has been ripped apart pretty well. However, after this one was detonated, some of the AN material spilled out onto the ground, which is exactly what we wanted to see. This means that after detonation, the energy level fell to the point that it could no longer self-sustain. The explosion died.” Taulbee adds that if a McVeigh copycat were to use this coated AN, the explosion would be much less deadly and damaging.

A major challenge in this work is to determine what concentrations of the fly ash coatings are necessary to reduce the power of the explosion while still allowing the AN to be useful as a field fertilizer. After the Oklahoma City bombing, scientists at the National Research Council (NRC) worked to make AN non-explosive not by coating it, but by diluting the ammonium nitrate with various additives, Taulbee believes. (Their tests were not made public, so he’s uncertain exactly how they were conducted.) The NRC concluded that a concentration of around 20 percent was necessary to make AN non-detonable.

“What we found was that a 15 percent coating is effective in stopping the explosion. This is good news,” Taulbee says jubilantly, “because the lower the coating



percentage, the less expensive this will be to manufacture. And in our pilot field tests, we’ve determined that the nitrogen release rate of the coated particles indicates that coated AN appears to be suitable for its intended use as a fertilizer.” He imagines that if such a coating is accepted by farmers, it would simply be an additional step in the established AN manufacturing process.

Taulbee says that this project has attracted national attention. The National Institute for Hometown Security recently awarded continuation funding for the project. “We’ve actually been identified as their top project,” he says. “It’s been showcased in Washington a couple of times, and they’ve fast-tracked our continued work on this.” Thurman and Paul Rydlund, president of El Dorado Chemical, one of two remaining AN manufacturers in the country, make up the research team for the initial project.

In the next few months, Taulbee will work with the Bureau of Alcohol, Tobacco and Firearms, scientists at the New Mexico Institute of Technology, and the FBI at Quantico, Marine Corps headquarters outside of Washington D.C., to get independent confirmation of his detonation results. Closer to home, he’ll also partner with Greg Schwab and John Grove in the UK Department of Plant & Soil Sciences, who will conduct plant growth studies, leaching tests, and soil migration studies to get a more extensive evaluation of the impact of coated AN on agricultural use and the environment.

“If Darrell Taulbee can eliminate much of the ‘McVeigh factor’ in ammonium nitrate, he’ll go a long way in helping contain the threat of these homegrown fertilizer bombs,” says Mike Matthews, one of Taulbee’s main contacts in the Office of Homeland Security.

Braden Lusk is studying the properties of aluminum mesh to lessen the impact of an explosion, work funded by the U.S. Navy.

Making Protective Mesh Stronger

Darrell Taulbee isn't the only University of Kentucky researcher working with high-impact explosives. Braden Lusk has been developing a mining research program at UK focused on the use of explosives, and he admits that this research interest began a long time ago—when he was 10 years old.

“As a kid growing up in Hutchinson, Kansas, I liked to blow up my toys,” he says, chuckling at the memory. “I would horde all kinds of fireworks, but I didn't use them on the Fourth of July. I had ‘greater uses’ for them. My parents had a lot of trouble understanding this hobby,” adds Lusk, an assistant professor of mining engineering.

He describes his current research focus as a two-sided coin. “We're looking both at how to make explosives more effective and also how to design materials to lessen the effects of a blast,” says Lusk, a robust and effusive man who came to UK from the University of Missouri-Rolla in 2005. His main focus over the last year has been on an aluminum mesh product for blast mitigation. This product development work is being funded for \$433,000 by the U.S. Navy through a company called Innovative Productivity Inc. in Louisville.

Lusk explains that this aluminum mesh could be attached to the windows of buildings near blasting sites, ship holds or as protective layers on mine-resistant, ambush-protected trucks, referred to as MRAPs. Large numbers of MRAPs have been shipped to Iraq. “And it's possible that soldiers in the field could use this mesh for protection,” Lusk adds.



And in his work there is a direct tie to the mining industry. Lusk talks about the Sego Mine disaster in January 2006 in Tallmansville, West Virginia, where an explosion trapped 13 miners beneath the surface, leaving only one survivor: “At the heart of that disaster was a seal failure that followed a methane explosion. The seals that failed at Sago had been tested and approved for a methane blast that was much less powerful than the blast that caused them to fail,” Lusk explains. “Even before this tragedy happened, there was a big push for the development of more blast-resistant mine seals, and I've thought about this material I'm working on and others like it as a good solution to protect mine seals.”

With the help of Kyle Perry, who has a degree in civil engineering (and also happens to be Lusk's brother-in-law), Lusk has been testing the mesh product in the field—an underground quarry in Georgetown, Kentucky. For “donating this space” to his work, he says he's indebted to Frank Hamilton, who owns the property, and his son Richard, both UK alums.

Perry and Lusk set up different thicknesses of mesh around an explosive charge with sensors directly behind the mesh, stand back a safe distance, and then detonate the charge. A sensor, with

no mesh in front of it, collects a reference pressure measurement from each blast to see how much the pressure is reduced with various layers of mesh.

“We're doing some numerical simulations using Autodyn,” Lusk explains, “a software program that models blast events, in conjunction with physical testing to validate the mitigating strengths of this mesh.” So far the researchers have shot over 150 tests, using a total of around 75 pounds of desensitized RDX, an explosive related to nitroglycerine and used by the military.

In corollary testing, Lusk is simulating blasts using a shock tube, a 120-foot-long reinforced steel tube with a 3/8" steel plate at the end and sensor mounts at different spots along the tube. Using less than a pound of explosives, he can send a shock wave down the tube and collect data that tell him the pressure time history of the wave.

“Field testing involves thousands of pounds of expensive explosives. Using this simulation testing is a lot less expensive and allows us to compare results between the field and tube tests.”

After he crunches the data from the tests he's done, Lusk hopes to draw up some guidelines for the use of this mesh, focused on the size and location of the blast. ■