Taming Explosives for Training

IT looks like a bomb. It even smells like a bomb—enough to fool man's best friend, the pooch who's trained to sniff out explosives. But it won't explode and won't even burn decently.

So who wants a dud like that? Not your average terrorist. But the bogus bombs fabricated of nonhazardous explosives for security training and testing (NESTT) by Lawrence Livermore are piquing the interest of scores of organizations responsible for calibrating explosive-detection machines and for training humans and dogs in detecting explosive devices. In fact, Lawrence Livermore is close to completing a commercial licensing agreement for NESTT.

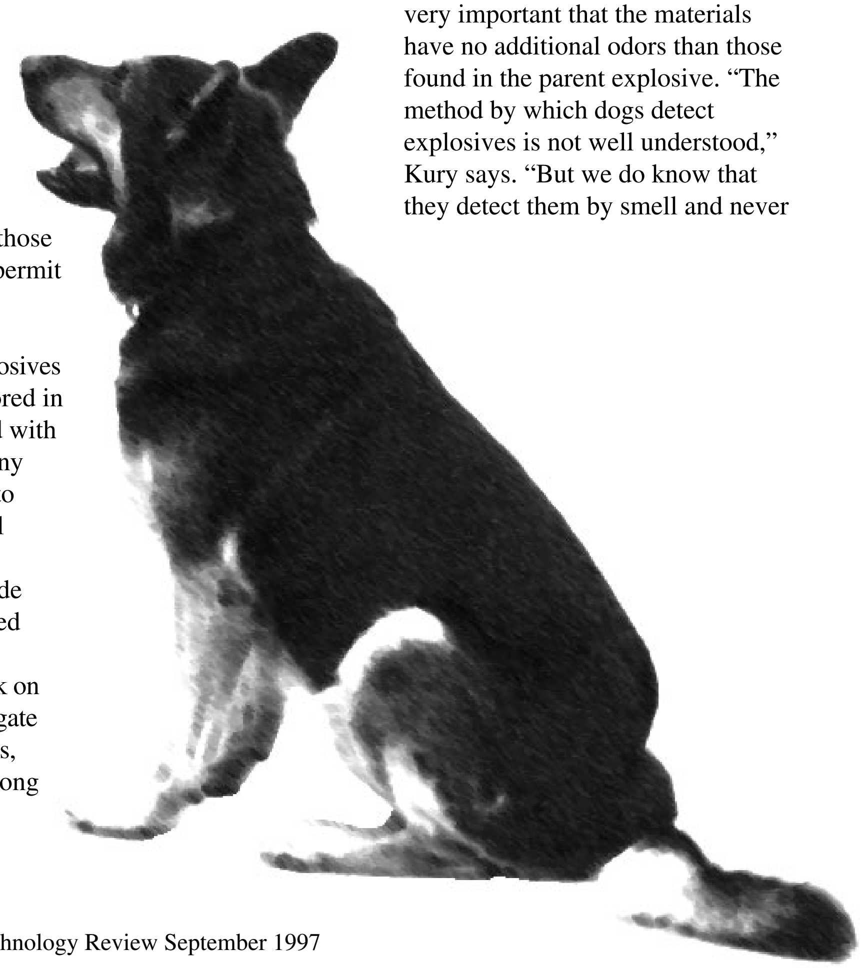
"We started the NESTT project about seven years ago," says John Kury, the explosives chemist who heads the project. "We had a fairly narrow need to provide a safe alternative to using actual explosives in training Livermore's canine explosives-detection teams, which have since been disbanded. As word got around about the project, we discovered a much broader need throughout the country."

When the Laboratory was training its own canine teams at the beginning of the decade, the teams had to use actual explosives and deal with the inherent dangers. Almost all the training had to take place at Site 300, the Lab's explosive test facility, where conditions certainly do not resemble those in an office building or airport. A safe substitute would permit training with a larger amount of material under far more realistic simulations.

But safety and realism aren't the only issues. Live explosives demand extra expense and care because they must be stored in bunkers or specially designed magazines and transported with special precautions. NESTT can be transported without any special precautions other than extensive documentation to prove that it is not what dogs and detection machines tell guards and police it is.

The simulated explosives made by Kury's team include stand-ins for TNT and a standard military explosive called Composition C-4 (Comp C-4), which contains RDX. By coating a layer of explosive that is a few micrometers thick on a nonreactive substance, Kury and his team produce surrogate materials that have many authentic properties of explosives, including vapor and molecular signatures. However, as long as the concentration of the parent explosive (TNT or RDX) is under approximately 8%, the materials remain nonhazardous. Kury says an early test was conducted in the Laboratory Director's conference room with about a pound of the simulated explosive—enough, if it were real, to completely destroy the room. "The dog hit it immediately," Kury says. "An animal acts differently in different environments. If you can train in real environments, there is a much better probability of a successful find."

In fact, preliminary results were so successful that larger quantities were prepared for a beta test program, which included U.S. and foreign canine units and companies that manufacture explosive-detection instruments.



Getting the Formulation Right

For the canine program, it was very important that the materials have no additional odors than those found in the parent explosive. "The method by which dogs detect explosives is not well understood," Kury says. "But we do know that they detect them by smell and never confuse glass with explosives. So it's important that the 'odor signature' of the parent explosive is maintained, and odorless silica was a natural choice for the substrate."

Kury and the team devised a formulation for dog training that uses 92% (by weight) fused silica of high purity as the substrate, onto which 8% TNT is deposited—rather like coating candy with an extremely thin layer of sugar. The formulation for the simulated Comp C-4 includes 8% RDX and 76.5% silica, along with the C-4 binder system (9.2% dioctal adipate, 2.7% polyisobutylene, and 3.6% oil).

The NESTT formulation for instrument testing is prepared by dissolving 3.3% polyisobutylene, 8.3% dioctal adipate, and 2.5% oil in pentane. That solution, along with 7.4% RDX and 78.5% cyanuric acid, is put in a high-shear mixer. The pentane is removed during mixing, and the resultant putty material is dried in an oven and molded into 2.5- by 5.0- by 30.5-centimeter bars, nearly identical to the Comp C-4 demolition bars produced by the U.S. Army. This formulation duplicates the oxygen–nitrogen ratio, effective atomic number, and density of the real explosive.

The materials have been tested in both small-scale laboratory tests and large-scale sensitivity tests, and they did not react in either the shock-sensitivity or flammability tests. Similar results were obtained by the Department of Defense when it tested mixtures of 15% or less of TNT or RDX mixed with sand.

Proof Is in the Tests

The NESTT canine test samples are formulated and packaged carefully to ensure that their odor signatures are identical to those of the parent explosives. Fused silica is also used as the packing material for shipping the samples to minimize the possibility of contamination by other organic compounds. To check the odor signature, Kury and the team use mass spectrometer analyses to verify that the vapor collected from TNT is identical to that from the NESTT TNT.

The test program has involved more than 200 handler–canine teams from U.S. and foreign agencies. More than 95% of the teams report that the canines react to the NESTT materials in the same manner they do to the parent explosive. And the 5% that did not react to the NESTT materials as they do to the parent explosive likely did so for reasons other than the authenticity of the NESTT explosive signature—e.g., the dogs were trained on "non-pure" parent explosive.

Several agencies have used only NESTT materials to train a few new canines. In all of these cases, the canines are able to detect samples of the parent explosives, TNT and C-4, reliably. These results, coupled with vapor analysis, verify that NESTT materials have authentic odor signatures.

While old Fido's nose can't be understood with scientific precision, the results of detection instruments can. So Kury's team sent samples to various organizations to see how the simulated explosives stack up against the real thing. Using nuclear quadrupole resonance, Quantum Magnetics of San Diego, California, found that the resonance of the nitrogen-14 isotope at 3.41 megahertz for RDX in NESTT was identical to that for RDX in Comp C-4, clearly indicating that the NESTT material can be used to calibrate detection machines (Figure 1).

Both TNT and RDX NESTT materials were tested by Thermedics Detection Inc. using its EGIS detection system, in which vapor and particulate samples are collected and the explosives are identified by analysis of selected decomposition products. The system detected the presence of explosive not only in the NESTT sample itself, but also on the courier's hands and the briefcase that was used to transport the sample (Figure 2). The following day, a canine being trained by the

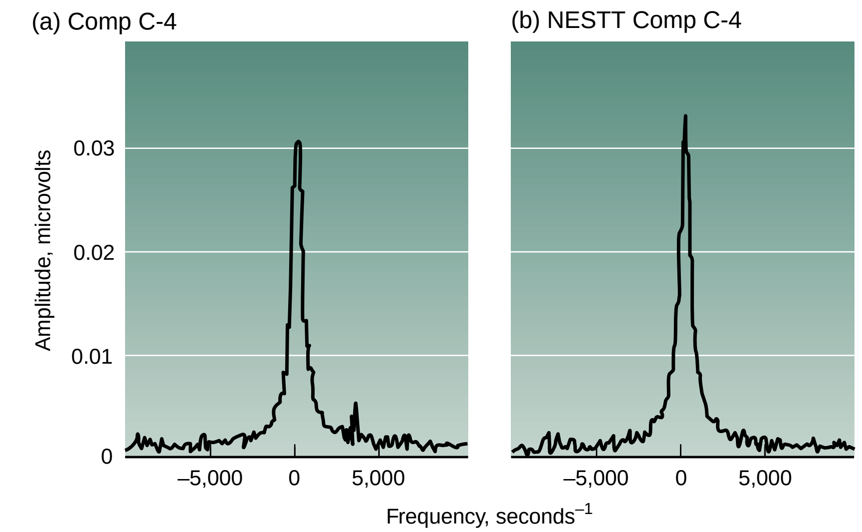


Figure 1. Nuclear quadrupole resonance spectra for (a) the explosive Comp C-4 and (b) NESTT Comp C-4 indicate that the NESTT formulation can be used to calibrate detection machines.

Connecticut State Police also reacted positively to the then-empty but still-contaminated briefcase.

NESTT Comp C-4 was tested on x-ray explosive-detection equipment made by Invision Technologies Inc. and VIVID Technologies Inc. Both tests gave positive results, indicating that NESTT has the same effective atomic number and density as a real explosive sample.

The beta test program demonstrated that the nonhazardous NESTT materials can benefit explosive-detection programs throughout the world. Few companies or agencies have the ability to use and store realistic quantities of explosives. With NESTT, realistic sites and scenarios can be used safely and economically to train canines that sniff out explosives and personnel who operate detection equipment.

—Sam Hunter

Key Words: canine training, nonhazardous explosives for security training and testing (NESTT), simulated explosives.

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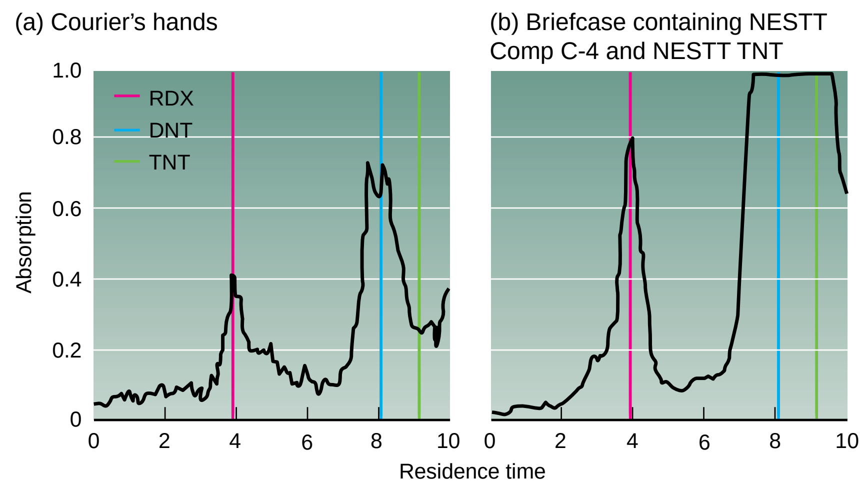

Figure 2. Chromatographic analysis (in arbitrary units) of the samples indicate the presence of RDX and TNT not only in the NESTT samples, but also (a) on the hands of the courier and (b) on the briefcase used to transport the NESTT materials.

Each month in this space we report on the patents issued to and/or the awards received by Laboratory employees. Our goal is to showcase the distinguished scientific and technical achievements of our employees as well as to indicate the scale and scope of the work done at the Laboratory.

Patents

Patent issued to	Patent title, number, and date of issue	Summary of disclosure
John C. Whitehead Joe N. Lucas	**Fluid Driven Reciprocating Apparatus** U.S. Patent 5,616,005 April 1, 1997	A pair of fluid-driven pump assemblies in a back-to-back configuration to yield a bi-directional pump. Each pump assembly includes a piston or diaphragm that divides a chamber into a power section and a pumping section. An intake–exhaust valve connected to each power section functions to direct fluid, such as compressed air, into the power section and to exhaust fluid. At least one of the pistons or diaphragms is connected by a rod assembly, which is constructed to form a signal valve. The intake–exhaust valve of one pump assembly is controlled by the position or location of the piston or diaphragm in the other pump assembly through the operation of the rod assembly signal valve.
Joe N. Lucas Tore Straume Kenneth T. Bogen	**Detection and Isolation of Nucleic Acid Sequences Using Competitive Hybridization Probes** U.S. Patent 5,616,465 April 1, 1997	A method in which a target nucleic acid sequence is hybridized to first and second hybridization probes that are complementary to overlapping portions of the target nucleic acid sequence. The first hybridization probe includes a first complexing agent capable of forming a binding pair with a second complexing agent, and the second hybridization probe includes a detectable marker. The first complexing agent attached to the first hybridization probe is contacted with a second complexing agent, which is attached to a solid support such that when the first and second complexing agents are attached, target nucleic acid sequences hybridized to the first hybridization probe become immobilized onto the solid support. The immobilized target nucleic acids are then separated and detected by the identification of the detectable marker attached to the second hybridization probe.
Raymond J. Beach William J. Benett Steven T. Mills	**Fiber Optic Coupling of a Microlens Conditioned, Stacked Semiconductor Laser Diode Array** U.S. Patent 5,617,492 April 1, 1997	A system for efficiently coupling the output radiation from a two-dimensional aperture of a semiconductor laser diode array into an optical fiber. The aperture is formed by stacking laser diode bars. Individual microlenses condition the output radiation of the laser diode bars for coupling into the fiber. A simple lens is then used to focus this conditioned radiation into the fiber. The focal length of the lens is chosen such that the divergence of the laser light after it passes through the lens is not greater than the numerical aperture of the optical fiber. The lens must focus the laser light to a spot size that is less than or equal to the input aperture of the optical fiber.
John F. Holzrichter Wigbert J. Siekhaus	**Method for Identifying Biochemical and Chemical Reactions and Micromechanical Processes Using Nanomechanical and Electronic Signal Identification** U.S. Patent 5,620,854 April 15, 1997	A method of operating a scanning probe microscope, such as an atomic force microscope (AFM) or a scanning tunneling microscope (STM), in a stationary mode on a site where an activity of interest occurs to measure and identify characteristic time-varying micromotions caused by biological, chemical, mechanical, electrical, optical, or physical processes. The tip and cantilever assembly of an AFM is used as a micromechanical detector of characteristic micromotions transmitted either directly by a site of interest or indirectly through the surrounding medium. Alternatively, the exponential dependence of the tunneling current on the size of the gap in an STM is used to detect micromechanical movement.
Charles E. Hamilton Laurence H. Furu	**Tunable, Diode Side-Pumped Er:YAG Laser** U.S. Patent 5,623,510 April 22, 1997	A discrete-element Er:YAG (erbium-doped yttrium–aluminum–garnet) laser side-pumped by a laser diode array which generates a tunable output around 2.94 micrometers. The oscillator is a plano-concave resonator consisting of a concave high reflector, a flat output coupler, an Er:YAG crystal, and an intracavity etalon tuning element. The oscillator uses total internal reflection in the Er:YAG crystal to allow efficient coupling of the diode emission into the resonating modes of the oscillator. The laser is useful for tuning to an atmospheric window, as a spectroscopic tool, for medical applications, and for industrial effluent monitoring.