Bomb testers beware: Trace gases linger

An underground blast at the Nevada Test Site on Sept. 22, 1993, heaved Rainier Mesa up a meter or more, then let the mountain fall back to its resting place. The only casualties were some trees that lost their leaves unusually early that year.

Scientists triggered this explosion, the start of the Non-Proliferation Experiment (NPE), to evaluate a sensitive new method for detecting clandestine nuclear tests. A ground inspection team armed with tubes for boring could find telltale radioactive gases from weeks to a year or more after an underground test, reports a group from the Lawrence Livermore (Calif.) National Laboratory in the Aug. 8 NATURE.

Lars-Erik De Geer of Sweden's National Defence Research Establishment notes in an accompanying commentary that the experiment proves "an on-site inspection has a good chance of finding conclusive evidence for a 'well-contained'" nuclear blast—the kind of test a cheater nation might stage. The success of the NPE thus bolsters the prospect of rigorously enforcing the Comprehensive Test Ban Treaty (CTBT), now being negotiated. The treaty would ban all nuclear testing, above and below ground (SN: 5/11/96, p. 298).

The NPE blast was not triggered by a nuclear device. In a chamber 400 meters underground, U.S. Department of Energy technicians rigged up more than a million kilograms of chemical explosives, comparable to a small, 1-kiloton nuclear bomb. The Lawrence Livermore team added two nonradioactive trace gases, helium-3 and sulfur hexafluoride, to substitute for the rare xenon-133 and argon-37 produced by a nuclear bomb.

Since the experimental blast, the group has tested hundreds of samples collected from tubes inserted 1 or 2 meters into the ground. They were able to detect helium-3 after 375 days and sulfur hexafluoride after only 50 days. Because of its small size, the helium molecule tends to pass into surrounding rock rather than rise directly to the surface, the report notes.

"I really think we have a breakthrough here," says lead researcher Charles R. Carrigan of Lawrence Livermore. Similar techniques could detect argon-37 from a nuclear bomb, even though a mere 15 cubic centimeters of the gas—"the volume of a Ping-Pong ball"— would be produced per kiloton of explosive yield, he explains.

Although the scientists had expected to detect the trace gases, they were surprised by the route those gases took to the surface. Carrigan thought the test explosion would produce fissures reaching up to the surface, but the blast was completely contained. So instead of traveling through fissures created by the blast, the gases rose through preexisting faults.

Even if an "evader" nation managed to test in a relatively fissurefree zone, Carrigan says, "all we need is one fracture" to send the gas to the surface. De Geer points out that the method can't guarantee detection, but "it certainly highlights a problem and a great source of uncertainty for the cheat."

Low barometric pressure, associated with storms, is needed to pull gases toward the surface, so weather conditions would influence the gases' arrival time. Diffusion alone, they calculate, would require "tens to hundreds of years" to produce detectable quantities.

Carrigan calculates that under the same weather conditions, a team monitoring a nuclear blast would have detected radioactive xenon-133 after 50 days and the lighter argon-37 after 80 days. The argon should remain detectable for more than a year, he adds.

Steve Stark/Lawrence Livermore Natl. Lab.

Lawrence Livermore scientists draw gas from a sample tube inserted in a fissure at the Nevada Test Site.

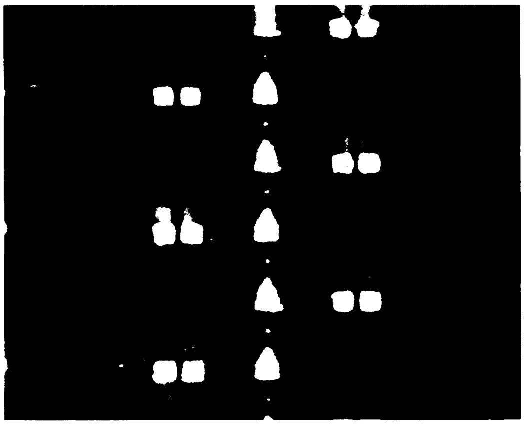
The new sampling technique will almost certainly become a part of the official detection network established by the CTBT, says Steven R. Bratt, director of the U.S. Nuclear Treaty Programs Office in Arlington, Va. — *E. Skindrud*

Counting millions of electrons, one by one

In his "Foundation" series, science-fiction writer Isaac Asimov coined the phrase "I don't give an electron" to mean "I couldn't care less." Researchers at the National Institute of Standards and Technology in Boulder, Colo., however, care about every electron in their pursuit of accurate electrical measurements.

Mark W. Keller and his coworkers at NIST have developed an electron pump that shunts electrons one by one onto a capacitor for storage. They have used the pump to count millions of electrons, missing, on average, only 1 in 70 million, they claim.

"With this device, electron counting has advanced from a novel laboratory phenomenon to a process that is accurate and reliable enough to be the basis of a new metrological standard of capacitance," says the NIST team in a report to be published in APPLIED PHYSICS LETTERS.



NIST

In this atomic force microscope image of the microcircuit at the heart of NIST's electron counter, the bullet-shaped regions in the center are micrometer-sized islands of aluminum separated by tiny tunnel junctions of aluminum oxide (yellow dots) on a quartz surface.

The NIST electron pump consists of a chain of six microscopic islands of aluminum separated by tiny patches of aluminum oxide. The patches act as tunnel junctions, allowing an electron to pass through only when an electric pulse is applied. A sequence of appropriately timed pulses forces an electron to pass from island to island down the chain to the capacitor. Only after one electron exits does the next electron enter the pump.

Thus, the pump can be used to place an exactly specified number of electrons into storage. "We call it an electron counter, but it's really an electron controller," Keller says. "We're forcing electrons to go through the device in a prescribed way."

"There's no limit on how many electrons we can pump through the device," he adds. The chance of an error, however, increases slowly as the number goes up.

By knowing exactly how many electrons a capacitor holds and carefully measuring its voltage, researchers can get a direct measure of the electric quantity called capacitance, which reflects charge-holding ability. — *I. Peterson*