*Charles Carrigan taking a sample of gas during infiltration experiment, NG09, October 2009.*

# 2009 Noble Gas Field Operations Test:

## Towards detecting "the smoking gun" during an on-site inspection

BY CHARLES CARRIGAN

Suppose you were transported along with 39 other people to a remote location in the world and asked to determine if an underground nuclear explosion had recently occurred. What would you look for? This question captured my imagination the first time I was confronted with the concept of an on-site inspection (OSI) 15 years ago.

Once the Comprehensive Nuclear-Test-Ban Treaty (CTBT) has entered into force, any Member State of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) can request an OSI if it suspects that another Member State has conducted a nuclear explosion. The area to be inspected may not exceed 1,000 square kilometres. If the OSI is granted by the CTBTO's executive body[1], up to 40 inspectors and their equipment will be transported to the area in question to commence searching for evidence of the nuclear test. The target of their search may be entirely contained beneath an area of only hundreds of square metres hidden somewhere in the vast permitted search area.

Before succumbing to the vision of a needle in a haystack, it is important to point out that the seismic and radionuclide detection capabilities of the CTBT's worldwide International Monitoring System (IMS) will probably have provided a good indication of the most likely places to look within the allowable search zone. If detonation products have leaked to the surface, gamma-radiation surveys can further help isolate the testing site. Localization may also result from over-flight observations as well as from distributed seismograph arrays set up within the total OSI search area that use post-explosion seismicity to pinpoint the underground location of the test. Finally, geophysical methods, similar to those used for mineral exploration, may also be employed in the search for the suspect site.

### MOST OBSERVATIONS ARE NOT UNIQUE TO AN UNDERGROUND NUCLEAR EXPLOSION

The activities described above can only locate the site of a possible violation. None of the methods mentioned can demonstrate conclusively that an underground nuclear explosion has actually taken place. This is because virtually all these observations are not unique to such an explosion. For example, underground explosions and their associated seismicity are common in the mining industry. Tunnels or boreholes containing electrical cables may be visual cues of an underground nuclear explosion or

[1] Once the CTBT enters into force, the Executive Council (EC) will act as the Treaty's principal decision-making body. It will consist of 51 members. Its main duties will be to promote the effective implementation of, and compliance with, the Treaty, and to oversee the affairs of the CTBTO. The EC will also receive, consider, and take action on requests for, and reports on, OSIs.

just mining, water-well pumping or construction activities. Even observations of nuclear radiation at the surface do not necessarily prove that a detonation has occurred recently. Legitimate nuclear processing operations or even old, pre-CTBT testing may be explanations of such observations. At this point, the hypothetical 40 inspectors have not found the incontrovertible evidence needed to show that a violation of the Treaty has occurred.

»Detecting significant levels of [radioactive noble] gases in the soil overlying a suspected underground test site is the best evidence – with the highest level of certainty – that a nuclear explosion has occurred very recently «

### METHODS TESTED TO CONFIRM RECENT NUCLEAR EXPLOSION ACTIVITY

Obtaining this "smoking gun" evidence of a violation of the CTBT is the primary goal of the equipment and activities that were recently evaluated in the CTBTO's 2009 Noble Gas Field Operations Test (NG09), held near Stupava, Slovakia. Underground nuclear explosions produce some extremely rare radioactive noble gases – isotopes of xenon and argon – that serve as excellent tell-tale indicators of very recent nuclear explosion activity. Gases produced by such explosions rapidly disappear in days or weeks by decaying into other elements. Thus, detecting significant levels of these gases in the soil overlying a suspected underground test site is the best evidence – with the highest level of certainty – that a nuclear explosion has occurred very recently.

It is within the capability of current OSI technology to detect concentrations of these gases falling below about one part in $10^{20}$ (1 followed by 20 zeros). This is less than the concentration that would result from mixing an amount of fluid the size of a ping-pong ball into a volume equal to that of all the Great Lakes in the United States. During an OSI, the analytical equipment capable of making these measurements is housed and operated in temporary labs set up at the base of operations of an inspection area. Tanks of gas extracted through tubes augered or driven several metres into the soil of the site of a suspected violation provide the samples that are analyzed by this equipment. Air samples are also taken to search for radioactive gases that may be seeping or venting from an undergroud nuclear

*Augering a shallow hole as a prelimnary to setting up a noble gas sampling site during NG09.*

explosion into the atmosphere. NG09, involving more than 40 researchers and observers from 17 countries including staff from the CTBTO, was about evaluating the operational challenges of preparing soil gas sampling stations, sampling soil and atmospheric gases and then analyzing them under both Treaty- and field-imposed conditions that might apply to a real OSI. The field test complemented the experience of the Integrated Field Exercise 2008 (IFE08)[2], which focused more on geophysical, observational and surface sampling techniques.

## REALISTIC SCENARIO CREATED IN THE SLOVAKIAN COUNTRYSIDE

The base of operations for the 10-day field experiment was set up in a hotel in the Slovakian countryside that had an indoor sports facility which was used to house several different prototypes of noble gas analyzers from China, Russia and Sweden. Participants were divided into teams that focused on soil gas sample-site preparation, subsurface sampling, atmospheric sampling, noble gas analysis and logistics. The Slovak military kindly provided the main field site for the operations test at a nearby army base.

On a typical day, one team might install soil gas sampling sites followed by other teams who would draw gas samples from the soil or the air. The samples were then returned to the base of operations for an analysis that would be used during a real OSI to look for the argon and xenon gases of interest. While the tell-tale gases of an underground nuclear explosion were not present in the operations test, most of the other elements needed to make the event realistic were present, including working amidst snow storms.

[2] For more information about the IFE08, please see www.ctbto.org/specials/integrated-field-exercise-2008/

*SAUNA analyzer (Xenon) during NG09.*

## NUMBER OF IMPORTANT LESSONS LEARNED

Proper utilization of the typically complicated suite of techniques and equipment exercised in NG09 requires a wide range of technical expertise. Since the completion of the field test in October 2009, the results have been analyzed by a similarly wide range of technical experts, yielding a number of important lessons. For example, we learned that extremely valuable time and effort in the field can be saved by performing all initial processing of gas samples at the base of operations and not in the field. Also, possible damage to critical processing equipment can be avoided by leaving it set up at the base to perform its tasks rather than transporting it to a sampling site.

We learned that hand-augering even shallow holes to set up soil gas sampling sites is labour intensive and may need to be performed many tens of times over large areas, suggesting the need for a small, rapidly deployed, vehicle-mounted augering system. We also learned the very practical lesson that collecting, transporting and processing gas samples in pressure-rated metal tanks, such as those used by divers, is far more efficient than using large bulky plastic sample bags.

*Preparation and quality check for noble gas sampling point during NG09.*

With respect to the techniques used for collecting a gas sample from the subsurface at the suspected site of an underground nuclear explosion, we found that the large volume (~ 1 $m^3$) of soil gas required for each sample enhances the possibility of dilution and contamination by atmospheric gases unless adequate precautions are taken during the extraction of the sample. Finally, because NG09 was the first exercise of its kind to integrate such a broad spectrum of OSI noble gas equipment, techniques and global expertise in a real-world field situation, we learned some very useful things about optimizing the value of future exercises. These are but a few of the many lessons that have already been gleaned from the events of last October.

To me, NG09 demonstrated that before we can achieve the desired "smoking gun" level of certainty in detecting an underground nuclear explosion under the most challenging of conditions that we might expect to encounter during an OSI, some components of the noble gas detection methodology must benefit from further development and testing. I also believe that this event serves as an excellent example of the kind of international scientific cooperation needed to ensure that noble gas detection methods will be practical and definitive under a broad range of challenging field and operational conditions.


### BIOGRAPHICAL NOTE

**CHARLES CARRIGAN**
is a geophysicist who participated in the 1993 Non-Proliferation Experiment (NPE) involving a buried thousand-ton chemical explosion at the Nevada Test Site in the United States that helped to demonstrate the feasibility of finding rare noble gases during an OSI. Dr Carrigan is a member of the U.S. delegation attending the CTBTO's meetings concerned with verification issues. He also conducts research on greenhouse gas sequestration and geothermal energy and studies volcanoes.