IPNDV Working Group 3: Technical Challenges and Solutions
Chain of Custody (6)—Technology Data Sheet

September 14, 2016

Chain of Custody (CoC) Technology Name: Tamper Indicating Seals & Enclosures

Physical Principle/Methodology of Technology:

Seals (or Tamper Indicating Devices, TIDs) are not intended to forbid access to a room or a container, but leave evidence of opening or tampering. Many different technologies are available and their cost and use depend on the needs of each specific application. For arms control, the number of seals deployed are typically fewer than would be required for safeguards, and the items being secured may be of significantly greater value (e.g., a nuclear weapon). For these reasons, maintaining CoC to provide confidence in item authenticity and integrity is paramount, while the costs associated with their deployment often receive lesser importance than they might in a safeguards context. Both TIDs and Tamper Indicating Enclosures (TIEs) require two broad features to be useful in arms control: a robust Unique Identifier (UID) and robust and redundant tamper indicating features.

Many references exist describing the various types of seals and how to use them. See References section below.

It is impossible here to list all the different seal (or TID) types. At the highest level, there are two categories of seals: those that require a hasp/hole and those that do not. Under each there are subcategories of active and passive, and under those there are various seal types, including loop seals, bolt seals, and adhesive seals. See table below. In arms control, it is expected that most inspections will be completed in-situ. In some instances, it may be possible to verify and perform forensic analyses offsite in the host party country, inspector's country, or a third party location.

	TID Type	Examples
Active	Loop Seal	EOSS, RMSA
	Bolt-type Seal	Smart Bolt
Passive	Loop Seal	Cobra, QuickSeal
	Bolt-type Seal	Relcor Guardian, Ultrasonic Bolt Seal
	Adhesive Seal	VOID-3, Confirm Tamper Tape, Reflective Particle Tag

A key distinction between TIDs and TIEs that is worth noting is that TIDs only provide one-point security, whereas TIEs provide whole container security (top, bottom, and sides. Not just entry). As mentioned earlier, the seals are used to provide evidence of the unauthorized opening of a room or container, controlling the opening of the door or of a lid. This supposes that the integration of the external walls of the room or the container can't be touched. In order to protect the enclosure as well, it is possible to use a TIE, a kind of external skin put around the objet to protect it.

TIEs can be either active or passive, depending on the access or the timeliness of the notifications required. There may also be some instances where active is not allowed, such as in a high explosive facility, and therefore passive is only option.

Additionally, the tamper indicating features can be incorporated into a TIE in one of two ways. They can be visually indicating so that no tools are necessary to detect tamper events. This could include the use of dye or color changing materials. Alternatively, a TIE could rely on a secondary tool to detect tamper, such as an eddy current inspection tool of a metallic container to detect cut and repaired holes.

In both cases, for TIDs and TIEs, the confidence created by their use is based on the use protocols and the security of the TID/TIE. Ideally, trust can be generated and maintained regardless of who is handling or installing the TID/TIE. It is also of upmost importance to keep seals and TIE under surveillance and dual control during their "lives," before use but also after use to avoid retro-engineering or use of parts to counterfeit installed seals. The same CoC discussed for the nuclear weapons applies to TIEs and TIDs.

When describing a TID in order to evaluate its usefulness in a specific arms control application, a description of the unique identifier is imperative. A seal without a highly secure unique identifier should not be considered for arms control use.

Examples Developed by JRC:

Ultrasonic Bolt Seals: These are mechanical bolts, used to close underwater stacks or dry storage casks. Each seal has an assembly of disks with cavities, randomly brazed together and when read by ultrasonic transducers, gives a unique identification signature. When the seal is removed integrity is broken, which is also read by ultrasonic transducers. For dry storage applications, an optical fiber is passing through the seal and connected to either an electronic seal (EOSS type) or a passive seal (Cobra type). The bolts are particularly resistant to harsh environmental conditions. In order to read the seals, a reading head and dedicated ultrasonic acquisition electronic and software system are needed.

- Low Cost Electronic Active Optical Loop Seal: Electronic TID connected to a plastic optical fiber up to 100 m long, communications protected by public/private keys.

Potential Monitoring Use Cases (e.g., chain of custody, nuclear material detection, explosives detection, etc.):

Chain of custody, containment verification, facility verification

Physical Description of Technology (e.g., approximate size, weight):

From a few centimeters (adhesive seals, bolt seals, etc.) to several meters (loop seal, TIE, etc.)

Time Constraints (e.g., measurement times, time to install the equipment):

It can take from a few seconds to several minutes for the installation, while verification would take significantly longer. The seals and TIEs will likely be inspected, analyzed, and reviewed at the facility at an inspector review station.

Technology Complexity (e.g., hardware, software, and ease of use by personnel):

Some basic seals do not need any specific hardware/software like mechanical seals for transport containers used for the supply chain. Some need specific readers to communicate with or verify the seals in-situ. In the case of seals used for nuclear safeguards applications, typically, inspectors require 1 ½ days training for using the reading system and associated software for understanding what signs of tampering to look for.

Infrastructure Requirements (e.g., electrical, liquid nitrogen, etc.):

From nothing to electrical connection to 110 V or 220 V mains. Portable battery-powered reading systems could be used as well. If needed, processing is done on laptop, tablet, or cell phones. May also

require networking, wired, or wireless infrastructure to collect monitoring data from active TIDs and TIEs, depending on agreed protocols.
Technology Limitations (e.g., detection limits for nuclear material, operational temperature range): Temperature range is from -20°C to 50°C, can be extended on demand. There also may be limitations due to battery lifetime, and facility constraints in locations where high explosives are present or where the technology may interact with the nuclear weapon.
Technology Development Stage (e.g., commercially available, development stage): At vast choice of seals is available on the market, the seals used for nuclear safeguards applications are certainly the most sophisticated and secure and could be applied for nuclear weapons containment. TIEs are less developed and are generally developed on demand for specific applications and type of container.
Cost Estimate: From a few Euros to approximately €2,000 per seal, TIEs could be more expensive depending on container size. Often, reading systems range from €100 to €3,000.
Additional System Functionality (e.g., outside the monitoring use case): If ever agreed to by both parties, remote monitoring could be a possibility, especially in the case of long-term storage monitoring.
Examples of Equipment: ESARDA Compendium developed by the C&S working group: https://esarda.jrc.ec.europa.eu/index.php?option=com_content&view=article&id=135&Itemid=263 2011 IAEA Safeguards Techniques and Equipment report: http://www-pub.iaea.org/MTCD/Publications/PDF/nvs1_web.pdf Two-volume TIDs test and evaluation report completed by Sandia National Laboratories: http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/25/041/25041005.pdf and http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/27/020/27020417.pdf. References exist on TIEs as well, even if less prolific than for seals. Survey completed by Sandia National Laboratories: http://www.osti.gov/scitech/biblio/1256541 U.S.–UK collaboration describing the potential use of passive TIEs in a nuclear weapons monitoring regime: http://www.osti.gov/scitech/biblio/1117098