1. Introduction

The Seals & Identification Laboratory (SILab) is a laboratory within the Traceability & Vulnerability Assessment Unit, part of the Institute for the Protection & Security of the Citizen from the Joint Research Centre of the European Commission.

In the nuclear safeguard community, SILab is well known for developing technologies and equipment based on ultrasonic control methods, suitable for sealing and/or identification of nuclear items. SILab has also developed recognized competencies in the field of electronic sealing, competences until now mainly deployed for transport and Customs applications. SILab developed its first electronic seals in the beginning of the 2000s for the automotive industry [1]. Regarding the commercial container security field, SILab developed seals (both actives and passives) and an integrated remote alarm system for containers [2]. SILab is also part of several pilot projects commissioned by the European Commission as technical expert independent from national and private interests.

Recently, the Italian Customs authority (Agenzia delle Dogane), under suggestion of DG TAXUD, asked for SILab expertise to solve some technical aspects regarding the dissociation of the harbour platform in two geographically separated entity, the harbour itself (loading/unloading of ships) and the inland hub (dispatching of the goods). Italian coasts morphology makes almost impossible the required extension of several harbours. For this reason, the harbour authorities are obliged to separate physically the loading/unloading of the ship and the dispatching of the containers. Inland hubs have been built or are in project, in which the containers will be dispatched and transported to (or from) the sea harbour only when the ship will be ready for loading/unloading. All formalities will be performed in the inland hub. This will require having a certified transfer between the inland hubs and the sea harbours. The system must ensure that the content of the containers is not altered during this transfer.

SILab proposed to the Customs and harbour authorities to demonstrate the potentialities and limitations of two types of electronic seals for this application. The first system is based on the use of passive RFID seals. This type of seal is extremely cheap but can be used only once. The second system is based on active seals that are smart tools functioning with active transponders. They are able to send a signal in a range of 30 meters, allowing automatic seal reading without the need of stopping the containers passing through Customs points. They are more expensive than passive seals but, at the end of shipping, after having downloaded the seal history, the seal memory can be cleaned and the seal can be reused.

The passive sealing system and the active one have been tested in the framework of the project “Il Trovatore” [3][4]. The goals of the project are to introduce new technology to make more efficient the execution of the logistics and Customs procedures and to define operational models that can be applied to different port and airport scenarios. JRC entered in the project in September 2008 with a collaboration agreement addressed at identifying innovative solutions based on RFID technologies for container sealing and for remote monitoring of goods during their trip from their arrival at the harbour up to when they leave the Customs area.

2. Description of the experimentation

2.1 Passive seals

The tested passive RFID seals [5] are based on the use of three passive RFID transponders. The seal is composed by a cylindrical body containing three passive transponders and by a metallic wire used to fix the bolt to the container. A closed seal is shown in Figure 1. The figure 2 shows a seal applied to a standard freight container.
Figure 1 – JRC patented passive seal closed with wire.

Figure 2 – JRC patented passive seal mounted to a container.

The passive transponders are the core of the seal. One transponder is permanent and its memory, that cannot be erased or rewritten, contains the unique identification of the seal and its history (manufacturer, date and time of installation, container number, date and time of seal breaking, etc.). Two transponders are sacrificial: the first one breaks when the seal is closed and the second one breaks when the seal is opened. The transponders in the seals are read through a portable reading system (Figure 3). Obviously, only the integer transponders can be read; therefore, if the seal is new, all the three transponders will be read; if the seal has been correctly installed, only two transponder will be read, whereas if a seal has been open (in authorized or not authorized way), only the permanent transponder will transmit information to the reader. The information from the portable reader can be sent via wireless communication to a central system aiming at managing the seal database.

This type of seals presents the advantage of being very cheap but can be used only once.

Figure 3 Portable reader for JRC passive seal.

Early prototypes of passive RFID system were tested in the framework of the Lithuania pilot project, launched in 2006 by DG TAXUD following a request from Lithuanian Customs Authority that experienced
a dramatic level of goods smuggling in the “Lithuanian Corridor” from Kaliningrad to Belarus [6]. This experience showed that the use of RFID passive seals improves the security of freight containers.

2.2 Active seals

The active seal developed at JRC [7] is composed by a main plastic body and an external cable (Figure 4a). One end of the cable is fixed to the body and cannot be taken out without breaking the seal itself. The other extremity is used to close the seal and, when inserted in the main body, is kept in place by a ring nut. The seal contains an electronic board (Figure 4b). This board is divided in two logical modules: the first one is a proximity reader for RFID passive tags (cable integrity check), the second one is an active tag interrogated by external readers during the seal checks. The two units are coordinated by a microchip containing a small memory.

The seal closing cable contains a passive tag at its extremity: when the seal is closed, the proximity reader gets the passive tag number, the microchip checks its identity and the information are written in the active tag. The identity of the passive RFID tag aims at avoiding that a seal is open and closed again with a cable different from the original one.

The advantage of this kind of seal is that the active RFID board can transmit a signal than can be read either by proximity readers or long distance readers. When using a long distance reader, that typically is permanently placed in strategic areas, the seal can be read from a long distance (up to 50m in open field), allowing the seal verification even when the sealed container is moving and eliminating therefore the need of stopping the container. Moreover, the seal memory can be cleared after usage, making the active seal reusable for many trips. The drawback is that they are more expensive than passive seals.

(a) (b)
Figure 4 – a) Closed active seal; b) electronics inside the seal.

The figure 5 shows an active seal mounted on a container.
2.3 The sealing system

A central processing unit has been setup at the Customs office. This unit contains and manages the seal databases, containing all the information related to seals coming from the different seal readers. The databases are updated in real time whenever verification is done with fixed RFID readers, as these readers are connected to the central unit through a wireless network. The information from portable reader is sent in real time whenever verification is done in an area covered by wireless network (for example in Livorno harbour the container parking area had wireless network coverage), otherwise it is done after the verification as soon as the portable readers are in a covered area. Whenever a reading is done with authorized portable readers, it is possible to see the whole seal history and to have an immediate feedback on the seal integrity. Whenever information from the readers are sent to the central unit, some checks are performed in order to give an alert when some inconsistencies are detected (e.g., the seal is open, the sealed container is not authorized to leave the harbour, etc.).

3. Results of the experimentation

RFID sealing systems have been demonstrated to Customs and Port authorities by simulating different scenarios of seal application, in particular the following operations have been carried out by using passive and active seals:

- Application of RFID seals to a container in Livorno harbour
- The container was not authorized to leave the Livorno harbour
- The container was authorized to leave the Livorno harbour and the seals were correctly setup
- Spot check of seals status between Livorno and Prato with portable readers
- The container arrives at destination Customs gate with integer seals
- Container arrives at destination Customs gate with open seals

The first operation, i.e. seal installation, is performed by authorized operators in the container parking area through portable readers. The portable readers are used to initialize the seals, i.e. to enable the usage of seals, and to update the seal databases indicating the container number associated to the seals as well as the time of seal installation. Portable readers are used also to verify and register the correct installation of seals. The verification is necessary to avoid that a seal is only apparently closed: if the seal is not locked properly, it may be possible to open it without leaving evidence. After the seal application, the sealed container has been loaded on a truck and brought to the Customs gate (figure 6) where an antenna for reading active seals was placed. If the container is in the list of containers authorized to leave the Livorno harbour, the exit barrier will open, otherwise, an immediate alert is sent to
the central unit and the exit barrier will remain closed.

Figure 6 – Sealed container leaving the Livorno harbour

During its trip from Livorno to Prato, the truck has been stopped for a spot check with portable readers (Figure 7) to show to the stakeholders that it is possible to check the seal status also far from harbour and hub infrastructures.

(a)  (b)
Figure 7 – Passive (a) and Active (b) seal status verification with portable readers during the trip from Livorno to Prato

When the container arrived in Prato hub, the active seal has been read by a fixed antenna placed in the entrance Customs gate (Figure 8) and the passive seal has been read with a portable reader. The seals were integer and the system notified that no anomalies have been detected.
In order to show the behaviour of the system when the seal integrity is violated, the seals have been broken and the container has been brought again to the Customs gate. In this case, an immediate alert has been sent to the central station as soon as the antenna read the active seal.

In a real working situation, the alarm would trigger a series of Customs and security checks performed by operators with the support of the information from the seal. Indeed, the seal contains the entire seal history and in particular the time of seal breaking/opening. It is noteworthy that by using the tested RFID sealing system, the Customs and security checks are done only when anomalies are detected. This is a fundamental advantage in order to speed up shipping operations without affecting the security of the supply chain.

4. Conclusion

The results of the tests were positive. The JRC demonstrated that the secure transport of container subjected to Customs obligation is possible with a system that has a very low impact on harbour and hub infrastructures.

Moreover, we showed that it is possible to make Customs checks very fast, as all the information of a container is retrieved from the database automatically by using seal information sent by fixed antennas and read without stopping the container transfer using active seals. These seals can be an optimal solution for transfer of containers from a site to another. They can be “cleared” after the transfer to be reused for a new transfer.

The use of passive seals instead of active seals should also be taken into consideration as they do not require any device installation in the site. With passive seals the container should be stopped for check, but only for few seconds in normal situations; indeed, if the seal verification is positive, i.e. the seal is integer, the container can proceed immediately.

In the described experiment, the containers are released immediately for dispatching (at the hub) or for loading on the ship (at the harbour) once the transfer have been validated by the Customs authorities. In the case of nuclear safeguard, the same seals can be used also for the continuity of knowledge during the storage of the containers.

5. Acknowledgments

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References