Surveillance and Containment Measures to Support IAEA Safeguards

The basic document on IAEA safeguards under the Non-Proliferation Treaty [1] identifies surveillance and containment as important measures which complement material accountancy in serving the main safeguards objective: timely detection of diversion of significant quantities of nuclear material. The word "surveillance" in the context of Agency safeguards is defined as instrumental or human observation to indicate or detect the movement of nuclear material. This article is devoted to the instrumental surveillance as mostly used by the Agency.

Surveillance instruments and devices are intended to indicate that either no nuclear material has left a certain location or that it has left only via legitimate routes. They also are used to indicate whether the integrity of the containment of nuclear material, such as containers, storages, reactor vessels, etc., was maintained or breached since last checked. In some cases surveillance devices facilitate the identification of items of nuclear material.

Surveillance instruments offer the possibility of increasing inspection efficiency and of reducing the inspection effort because they can be operated unattended for long periods of time. Instrumental surveillance provides permanent and reliable records, such as films, tapes, monitor readings, etc., which can be used by the inspectorate for evaluation. One of the limitations of the surveillance equipment currently available is that, in most cases, it does not indicate the amount of nuclear material removed. For example, the exact number of irradiated fuel elements during reactor reloading, or the number of elements loaded into a shipping cask cannot be ascertained from an optical record of the operation. Surveillance cameras can give only a record of the movements of the refuelling machine or of the cask with time indication of such movements depending on the instrument. However, the absence of this capability is compensated for by the fact that the IAEA has developed a well-balanced safeguards system in which surveillance is used in combination with other techniques to give the required confirmation that the reported movements of materials are essentially correct. The importance of surveillance is enhanced in situations where non-destructive assay methods cannot be satisfactorily applied.

The Agency has accumulated considerable field experience in the routine use of surveillance equipment. This experience has demonstrated the value of the application of surveillance measures. On the other hand, it has brought to light certain limitations in the capabilities of the equipment and indicated the need to utilize the most advanced techniques to overcome these limitations. One of the continuing tasks of the Division of Development and Technical Support is to pursue a research and development programme toward this objective. This programme was drawn up, and is reviewed periodically, in consultation with inspectors and it is carried out in co-operation with national research centres, laboratories, firms, etc. The development programme has received further impetus as a result of decisions of some countries to provide technical support for the further strengthening of IAEA safeguards.

Photographic surveillance system is based on the Super-8 Minolta camera. Most of the present surveillance systems in routine use are of this type. A recently developed model, employing a miniature electronic timer instead of the electromechanical triggering device, is being tested at IAEA headquarters and in the field.

Moving from the general requirements for surveillance to the identification of the specific characteristics of the equipment needed, these can be itemized as follows. The equipment must be: (a) reliable; (b) capable of unattended operation in plants over a long period of time; (c) tamper-proof/tamper-indicating; (d) efficient; (e) easy to service; (f) capable of operating with a minimum of maintenance; (g) capable of operating without interfering with plant activities. In addition, the unit cost should not be high.

For some safeguards equipment, portability is a necessity; for instance, the equipment for non-destructive measurements has to be taken by inspectors to several countries in the course of a single mission. For surveillance equipment, portability is not essential, so long as the equipment is transportable and it can be readily installed at the plant where it should continue to work for several years. However, the importance of the reliability of the equipment cannot be too greatly stressed since, in some cases, instrument failure means that, unless duplicate instruments are in use, essential information is missing which can only be obtained by re-establishing the relevant physical inventory, which is a very costly and time-consuming task.

One difficulty is that commercially available surveillance instruments and devices often do not meet the Agency's requirements and the Agency has had to develop its own equipment. This has been done economically by using standard commercial products of proven reliability as much as possible.

The simplest — and oldest — Agency surveillance device is the seal, which has been used in great numbers during the past decade. Seals are used to ensure that the breaching of the integrity of containment will be detected. The seal consists of two metallic halves which can be interlocked. A piece of wire is used to attach the seal, the ends of the wire are tied inside the seal before locking it. The seal is designed in such a way that any attempt to open it, would be detectable. The drawback of this device is that its replacement by a counterfeit cannot be detected in the field. The substitution can be determined only at the Agency's headquarters by the use of a microphotographic comparison method. This means that the seal must be replaced and brought back to the Agency.

To overcome these difficulties, projects to develop improved seals and sealing methods were started. Seals currently under development include those based on fibre-optics, which provide the possibility of verifying the integrity of the seal by the inspector in the field. The seal is checked by examination of the continuity of the fibres in the bundles of the sealing loop by observing or photographing the transmission of light through the fibres. The fibres in each seal create unique patterns of light-spots, which serve as the "fingerprint" of the seal. As a result, there is no need to replace the seal to verify its integrity. Intensive field tests will define the future applications for the fibre-optic seal within the frame of IAEA safeguards.

The Agency has also encouraged research work on the development of electronic seals. A first prototype is a self-monitoring and self-powered seal which gives a coded display that automatically changes with time. Although the display can be read by the operator of the facility, the correct display sequences are known only to the inspector. Thus, the seal can be checked during each inspection. An additional promising feature is that an inspector may telephone or telex the operator of the facility and obtain the reading displayed on the seal. The reading will tell the inspector whether the seal has been opened or not.

In addition to carrying out its own development programme for seals, the Agency receives information about development work on seals in some Member States. Amongst the techniques monitored in this way is the use of the ultrasonics for identification of seals. Seals have been developed which, when scanned with an special ultrasonic apparatus, produce an ultrasonic reflection pattern that is unique for each seal.

Surveillance instruments based on optical or electro-optical components can provide information about the movement of nuclear material or the integrity of containment. To this end, a number of photographic systems, based on commercially available still cameras and on Super-8, 16 or 35 mm movie cameras, were produced. Features of these assemblies include timing devices which trigger the camera to make single exposures at preset intervals and a tamper-indicating housing. Typically, a system is installed at a plant in a properly chosen location and keeps watch over sensitive areas such as the reactor head, the spent fuel pond, etc. Evaluation of the exposed films enables the inspector to ascertain if that reactor reloading, shipment of spent fuel, etc., has been done along legitimate routes and in accordance with the schedule reported to the Agency. The system may be powered by batteries or by the main electrical supply. Occasionally, batteries may be exhausted earlier

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Television surveillance system with infrared emitter eliminates the need for film processing. The video system under development offers additional advantages such as a very large frame capacity, high reliability and selective recording of events. ▶


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Table 1: Some Minolta System Data

Model	Status of use or development	Weight (kg)	Dimensions (mm)
Mark 1,2	Fully proved; over 5 years in use	18.2	490 X 330 X 335
Mark 3	Testing in Headquarters	4.7	240 X 215 X 330
Mark 4	Testing in Headquarters and field	2.6	95 X 125 X 290

than desirable, especially when the system operates under extremely adverse environmental conditions. This tends to decrease the reliability of the system. The use of a main power supply, of course, eliminates this problem but creates dependency on the facilities power source.

The availability of a range of photographic surveillance systems permits the selection of a unit that matches most nearly a given set of conditions. However, the Agency has found that a system based on the Super-8 Minolta camera proved to be the most suitable and the bulk of surveillance assemblies installed are of this type. Accordingly, efforts have been concentrated on improving this system and the following improvements have been made:

- extended capability to record events under poor illumination
- easier installation and service on-site
- extended unattended operation time on a set of batteries.

The extension of battery life was achieved by replacing an electromechanical triggering device by a specially designed electronic timer. In addition, the size and weight of the system has been considerably reduced (see Table 1).

However, film surveillance systems have limitations arising from the conditions under which they have to operate and some of these limitations are inherent in the system itself, for example:

- limited frame (picture) capacity (Minolta camera 7,200 frames);
- the necessity to process the films (this prevents discussion with the plant operator of the recorded information during the inspector's visit);
- inability to record under very poor illumination or over a wide enough range of illumination;
- access limitation to service units in case of high radiation or contamination;
- film limitations due to radiation environment;
- no direct dating of recorded events on the Minolta system;
- occasional failure under extreme environmental conditions.

To overcome these limitations, an intensive study was undertaken to find alternative approaches. The study pointed to the use of television cameras combined with videomagnetic recording and several prototypes were designed, constructed and tested at the IAEA headquarters and, in co-operation with inspectors, in the field under different plant and environmental conditions.

In general, a TV surveillance system consists of a camera remotely operated by the control unit. The latest versions allow the use of two cameras per control unit, with a built-in video "splitter" which divides the screen into two parts whose relative areas are adjustable. Each camera can be located as far as 500 metres from the control unit. The Hitachi HV-16 camera was modified to increase the light sensitivity by 80 times; it automatically adjusts to the light changes and gives acceptable quality of the picture in the range 0.5–100,000 lux. The multidiode target vidicon is sensitive not only to visible light, but also to the infrared range (800–1100 nm). This feature enables cameras to be equipped with infrared emitters which will illuminate the area and allows the recording of events even if the regular light is switched off completely. The use of self-illumination, such as flash, for camera surveillance was considered a long time ago, but the idea was not pursued on the grounds that the flashes might disturb operating personnal. It is likely that the use of infrared will not be intrusive and will help to solve a few problems. The camera is designed to work reliably under environmental temperature conditions from $-10^{\circ}C$ to $+50^{\circ}C$.

All the components of the control unit (video recorder, triggering device, video calendar/clock, emergency power supply etc.) are built into a sealed housing. The Hitachi SV-612 time lapse video recorder has been modified for this purpose and permits the recording of 180,000 single frames on a standard 720-metre magnetic tape. This means that, on average, a single tape can be used for a plant area under surveillance for about a year. The built-in crystal-controlled clock system superimposes on each picture the month, date, hour, minute and second, when it was taken. An electronic triggering device enables a wide range of interval between pictures or groups of pictures, to be selected. The system can operate on European and American power supplies as well as on 24-volt batteries. The power requirement of the system is relatively low, approximately 250 watts. It was found that dependency on the facility's main power supply is not a crucial problem in using a TV system because the control unit for the system can be located in any convenient location where it can be connected to the facility emergency power supply, which would restore power to the system a few minutes after interruption of main supply. Rechargeable batteries built into the control unit of TV systems automatically supports the system for a few hours in any event.

The principal advantages of the TV surveillance system are:

- it has a very large frame capacity;
- no film processing is required;
- the recorded information can be obtained without entering a contaminated area;
- the recorded information is always ready for evaluation on the spot or at headquarters;
- it incorporates on each picture the date and time when it was recorded;
- it is more resistant to radiation than film cameras;
- it has the ability to record events under a wide range of lighting conditions and the use of infrared illumination promises to provide the capability of recording events even when there is no visible light.

The first TV surveillance system was installed over a year-and-a-half ago, and several systems have been installed in facilities in Asia, North and Central Europe and America. The field experience already accumulated has demonstrated that the system is very reliable; it operates without any major problems and has not required maintenance work. In addition, the system still has considerable potential for development.

There are other types of surveillance equipment under development, for example, a family of monitors, some to count the number of spent-fuel bundles discharged from a reactor, others to identify bundles, yet another type to measure flow or level of liquids containing safeguarded material in reprocessing plants, etc.

The importance has been recognized of maintaining an on-going development and testing programme directed at finding an optimum combination of different types of surveillance equipment for each kind or safeguarded facility. A part of the progress in this respect was reported at the International Conference on Nuclear Power and its Fuel Cycle [2]. The long-term IAEA experience in the use of surveillance and containment measures for international safeguards has demonstrated their effectiveness and usefulness. Many people within and outside the Agency have contributed to the achievements outlined above. Starting with some simple surveillance devices, the Agency has made great strides forward and is now engaged in the development of more sophisticated, efficient and reliable equipment and techniques in order to contribute to the further improvement of IAEA safeguards.

References

[1] "The Structure and Content of Agreements between the Agency and States Required in Connection with NPT", INFCIRC/153, Vienna,1972.

[2] A.J. Waligura, Y. Konnov, R. Smith, D. Head, J. Hodkinson, "Safeguarding on-power fuelled reactors — instrumentation and techniques", Paper presented at the International Conference on Nuclear Power and its Fuel Cycle, Salzburg, Austria, May 1977.