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Containment and Surveillance Devices

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Abstract

The growing acceptance of containment and surveillance as a means to increase safeguards effectiveness has provided impetus to the development of improved surveillance and containment devices. Five recently developed devices are described. The devices include one photographic and two television surveillance systems and two high security seals that can be verified while installed.

CONTAINMENT AND SURVEILLANCE DEVICES

The growing acceptance of containment and surveillance as a means to increase safeguards effectiveness and to optimize IAEA inspection efforts, has provided impetus to the development of improved containment and surveillance devices. Emphasis is now being placed on programs to demonstrate reliable equipment which can be conveniently used in the field by Agency inspectors. Several efforts in the United States to achieve this goal include the development of unattended photographic and television systems for surveillance, and high security seals for containment.

OPTICAL SURVEILLANCE SYSTEMS

Surveillance cameras are used by IAEA to provide information about plant operations and the handling of special nuclear material during an inspector's absence. Applications include the surveillance of spent fuel storage bays, access points to storage bays or controlled areas, enrichment plant feed and takeoff points and product loadout points of reprocessing plants.

Photographic Surveillance Camera

A prototype photographic camera system has been developed to provide the IAEA with several capabilities in an instrument of small size. The major subsystems of the secure surveillance camera are a single frame camera, timer, day and time display, tamper indicating features, and power supply. The camera photographs a scene and the day and time display when it is actuated by the programmable timer. The tamper-indicating features irrevocably record attempts at altering the operation of the camera or the recorded data.

The system incorporates a Minolta XL-400 Super 8 movie camera, Figure 1, which is used in the single-frame mode. This camera has a through-the-lens automatic exposure control which enables it to be used in any reasonable existing light. The only modification made to the camera is the addition of a battery-charging circuit which keeps the two camera batteries charged.

The time base for the clock, calendar, and periodic and random interval timers is a crystal-controlled oscillator. The periodic timer circuitry triggers the camera at selectable intervals (10 to 90 minutes in 10-minute steps). The pseudo-random timer produces a pseudo-random time interval sequence that will not repeat for over a year. The minimum time interval is selectable (1, 2, 4, 8, or 16 minutes), and the maximum interval is 16 times the selected minimum.

The day and time are displayed on a 7-digit, light-emitting-diode display. The display is superimposed on the picture frame through a series of two mirrors and a lens. A 4-digit mechanical counter is used to indicate the number of frames exposed. The counter is visible through the front window of the tamper-indicating enclosure.

For any unattended instrument, the validity of its recorded data must be assured. To provide this assurance, the camera and its associated electronics are housed within a tamper-indicating enclosure consisting of a mirrored glass cylinder, and an anodized aluminum end cover which are joined by a seal. The surveillance camera system includes an electrical power monitor which actuates an irreversible electromechanical counter also contained within the enclosure. Any attempt to remove or alter the electrical input voltage to the camera causes the counter to increment.

The power supply is the only part of the surveillance camera system which is outside of the tamper-indicating enclosure. In addition to converting 110 Vac to 16 Vdc, it includes batteries to provide power for 24 hours if the main power fails.

Advanced Television Surveillance System

An advanced television surveillance and recording system has been developed to provide long-term unattended surveillance of activities at nuclear facilities. The TV system for the long-term surveillance has some special features such as dual CCD cameras in tamper indicating/environmental housings; tamper-detecting transmission lines; slave video recording unit; and video cassettes for the ease of tape threading. Access points to the cameras and recording console are secured by tamper-indicating seals. The television system is controlled by a microprocessor which permits various unique operational features to be incorporated into the system. The microprocessor and the remainder of the system utilize CMOS logic to reduce power and to extend system operational life when loss of main power requires operation in the battery-backup mode.

The mechanical configuration of the unattended television system is modular (Figure 2) and permits adapting the basic system to different surveillance requirements. The base for the system can be used as a support base or it can be filled with batteries to supply power for longer periods of operation without AC mains power. A master console contains all the electronic assemblies and also supplies a limited battery backup capability with rechargeable cells. The console contains two video recorders which can be operated individually or with one serving as a backup for the other. Both recorders can also be operated simultaneously to provide reliability through redundant recording. The slave recording unit contains a third recorder that utilizes a special locking video cassette. The video cassette can be removed from the slave unit without disturbing the system operation. Operation of the locking mechanism in the video cassette is controlled by the microprocessor when it receives a request from the inspector for access to the slave unit. The microprocessor will command the recorder to fast forward the cassette thereby locking up the cassette before access is permitted to the slave unit. Playback of the video information contained in the slave recorder cassette requires the drilling of special holes to remove locking pins in the cassette. The slave recorder and its cabinet are also optional to the system and may or may not be installed, as desired. The unattended television system uses two CCD cameras which are designed to operate at low voltages from the battery supply. The cameras will receive from 12 to 35 volts depending upon the length of the coaxial cable between the camera and the master console. This single cable is all that is required for installation of the CCD camera. A special multiplexing line supervision system protects the single coax against line tampering. The TV cameras are driven by special dual sync generators inside the master console that automati- cally detect failure in either of the generators and switchover to the operating generator if a failure occurs. An auto iris on the camera will adjust it for varying light levels. The camera which utilizes a unique design whereby the printed circuit boards are fitted around the lens assemblies can accept a wide variety of focal length lenses varying from 12.5 milli- meters to 75 millimeters.

The master console receives the incoming video and demultiplexes it to feed it to a video mixer where the two cameras are combined. Date, time and status information concerning tampers, battery operation or motion detection is added in the character generator. The output of the video mixer is sent to the three recorders, the video analysis circuit, and the motion detect circuit. The motion detect circuit samples the video at designated points and determines that motion is occurring in the combined picture.

A video analysis circuit is used to determine if the recorders are recording the video signal and will detect a failure if either of the video signals or sync is absent. This circuitry and the other features provided by the CMOS 1802 microprocessor enables the system to develop self-diagnostics information. The results of the self-diagnostics are available to the Agency via an interface which will permit connecting the system to the remote monitoring units being developed for the Agency.

The microprocessor system also enables a number of the inspector's operational functions to be simplified. All functions are initiated via a keyboard next to the video monitor contained in the master console. The potential for human error has been reduced by appropriate software programming of the microprocessor to provide automatic operation, test sequences and fail-safe start of the systems.

Battery Operated Television System

A battery-operated portable television surveillance system has been developed to provide a surveillance capability to monitor special activities such as refueling of a LWR reactor. The system is packaged in two aluminum cases (Figure 3). One case consists of a video cassette tape recorder, a small television monitor, a battery charger, a sealed lead acid battery and the control circuitry for the system. The second case houses a tripod, a Charge Coupled Device (CCD) camera, associated cable, and extra cassettes.

The battery-operated system is designed to be set up and placed into operation in a minimum of time. The system provides an inspector with the capability of monitoring an activity at selectable time periods between one and 15 minutes (in one minute increments) for a surveillance duration of up to 24 hours. At each interval, the controller for the battery-operated system turns on the tape recorder and records approximately one second of video. The controller also places the time of occurrence of the recording and the day number into the video. The case containing the controller and recorder receives the video signal from the sealed tamper-indicating camera housing via a fiber optic cable The use of this type of cable makes attempts to tamper with the video quite difficult. If the power line to the camera housing is interrupted or shorted, the system will detect the loss of power and automatically record a tamper indication in the video. If the video cable is broken, then a second tamper-indication will appear in the video recording. Both tamper indications can be observed by the inspector during playback.

A special tamper-indicating circuit permits an inspector to detect if the recording case has been opened in his absence. The inspector, before closing the case, enters a code, selectable from one million different numbers into the controller. When he reopens the case, he enters the same number for comparison with the number stored when the case was last closed. If the numbers match, a green light appears. If he does not see a green light, he can be reasonably assured that someone has opened the case in his absence.

SEALS

Seals are often used to provide containment of special nuclear material or security for unattended instrumentation. The integrity and identity of the seals currently being used cannot be determined while the seal is installed. Two new seals, one passive and one active, have been developed to provide the Agency with this capability. Both seals utilize fiber optic bundles as the sealing "wire." Fiber optic seals are a new class of high security, tamper-resistant/indicating seals whose integrity and unique identity can be established in the field without removal or disassembly. In addition, this type of seal has the capability of being both continuously and remotely monitored.

Passive Fiber Optic Seal

The unique identity or fingerprint of the passive seal is established at the time the seal is assembled in the field by recording the random positions of the ends of glass optical fibers which make up the sealing loop. This recording can be accomplished either photographically or by noting the coordinates of a small subset of fibers. A direct comparison of a negative taken at the time of the seal assembly with a positive print taken at a later date (when the integrity of the seal is being checked) provides the highest level of confidence that a seal has not been compromised. For less demanding situations, a comparison of the coordinates or relative positions of a small number of fibers should be satisfactory.

In principle, the high level of security which is offered by fiber optic sealing devices depends upon the unique fingerprint which is generated during assembly by the completely random pattern of the 225 ends of the 0.06mm diameter optical fibers in the bundle. The uniqueness of this fingerprint is further enhanced by the imperfections in shape and optical characteristics of the individual fibers in the bundle. This fingerprint will be destroyed during any seal disassembly, complete withdrawal of one end of the fiber bundle from the seal assembly block or severance of the bundle. Duplicating this unique fingerprint would be a formidable task should the original seal be reassembled or replaced with a substitute.

The passive fiber optic sealing system consists of four elements; the seal (Figure 4), assembly tool, hand-held microscope and instant print camera. The fiber optic seal employs a plastic, hexagonal shape assembly block and a polyvinyl-jacketed bundle of glass fibers. The block holds the two ends of the bundle firmly in place and insures the complete mutual interpenetration of the fibers during the assembly procedure. During manufacture, one end of the fiber bundle is permanently emplaced in the assembly block. At the time the seal is completed in the field, the free end of the fiber optic bundle is inserted into the assembly block and secured with the aid of an assembly tool. The unique fingerprint of the seal is then immediately documented by either visual observation or by photographic means using the hand-held microscope and special instant print camera. During subsequent inspections, verification of the fingerprint is accomplished by comparing the seal fingerprint with either the visual observation or the original photomicrograph.

Active Fiber Optic Seal

The active fiber optic seal is a security seal that continuously monitors the integrity of a fiber optics loop and displays the status, opened or closed, in a simple manner. The status of the seal can be identified by observing the seal's optical display, as shown in Figure 5. The observation can be made by a representative of the inspectorate that installed the seal or by a representative of the operator within whose facility the seal is installed (with the observation reported to the inspectorate).

As a security seal, the active (or self-monitoring) seal provides several unique capabilities: High security, field verification while installed, remote verification, time resolution of integrity, and reusability. This seal is intended for use in applications that require one or preferably more of these features. The sealing of containers for large quantities of strategically or economically valuable materials is one potential application. Unattended instrumentation used to monitor such material may also require the use of a seal with these features to assure the validity of the data collected.

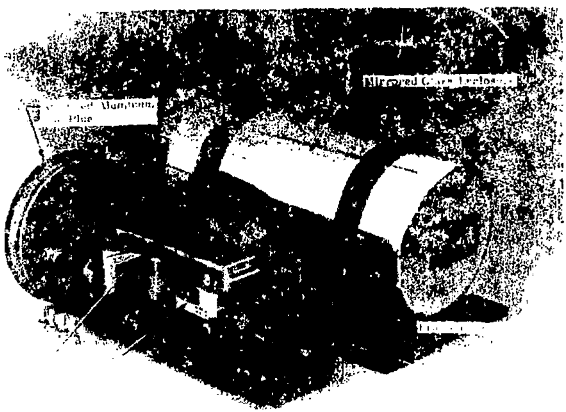
Each seal is programmed by a special piece of equipment to display unique sequences of different numbers and letters. These sequences of displays provide the identity of the seal. For each seal, the display will change at preset intervals, once every 1, 2, 4, 8, 16, or 32 hours. Unlike other seals that provide their complete identity at all points in time, the information that identifies this seal is distributed through time.

Each seal can be reused by reprogramming the display generator with one of more than two million unique sequences and by installing fresh batteries, if necessary. The batteries contained within the seal are sufficient to operate the seal for six months over a temperature range of 0°C to 50°C.

This seal consists of two major parts: a fiber optics loop and the electronic monitor module that verifies the loop's integrity. When a seal is in use, the loop integrity sensor transmits light pulses into one end of the fiber optics loop. If the pulses reentering the electronics package from the other end of the loop do not correspond to the pulses transmitted, the display generator indicates a violation by changing the sequence of displays produced after that time. The module utilizes a custom designed large-scale integrated circuit to control the generation of display sequences. The integrated circuit and batteries are enclosed in a tamper-responding container. Any attempt to gain access through the container to the integrated circuit results in the interruption of electrical power to the circuit. Since the programming information is stored in a volatile form, loss of electrical energy causes loss of this information. Correct display sequences cannot be reported after this has occurred.

The normal operational cycle for the active fiber optics seal is as follows: (1) the display generator is programmed and started at the Agency's headquarters just prior to the module's deployment to the host's facility; (2) an inspector attaches the module to the fiber optic loop on the item to be sealed; (3) the facility host reads and records the display at the intervals requested by the Agency and reports the information at times selected by the Agency; (4) during each visit by an inspector to the host's facility, the seal's point of application and the seal's integrity (correct display value) are verified. (5) during these visits, the electronic modules approaching the end of their [illegible], [illegible] battery life or number of [illegible] [illegible] [illegible] modules that have been [illegible] [illegible].

The five devices described above [illegible] [illegible] program to develop and make prototype [illegible] and containment equipment available for [illegible] by the Agency. The results of the Agency's evaluation will determine what additional development or design changes may be necessary before initiating production or [illegible] capability by commercial suppliers.



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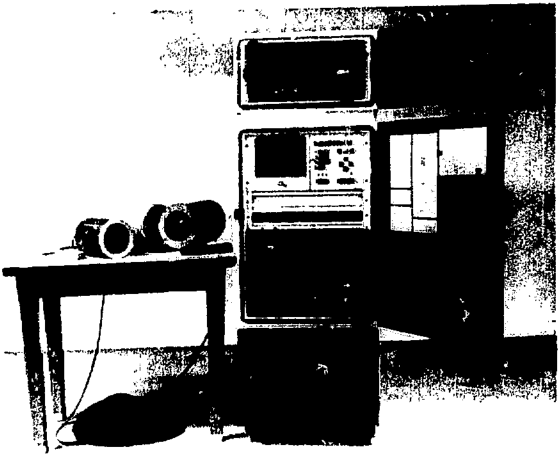

Figure 2. Advanced Unattended Television Surveillance System

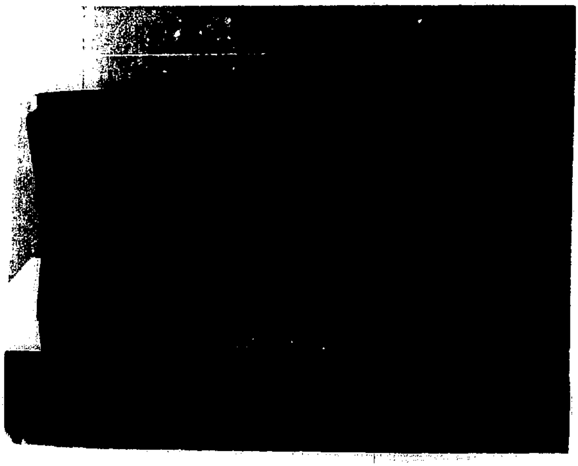

Figure 3. Portable Battery Operated Television Surveillance System

Figure 4. Passive Fiber Optic Seal

Figure 5. Programmer and Active Fiber Optic Seal