Health Dosimeter Plays an Unusual Role as a Safeguards Device

by Robert Schaer

In nuclear facilities where highly radioactive material is processed or handled, such material is generally transferred or moved according to routine, predetermined procedures. Under the standard IAEA safeguards agreements, material accountancy is the fundamental safeguards measure, with containment and surveillance as complementary measures.

For many years, the IAEA has utilized surveillance cameras in reactor facilities. These fully automatic and tamper-resistant devices mainly watch the routine transfer points for fuel bundles, such as pools or hatches. Another device used by the IAEA is the seal. Identifiable seals are applied, for instance, at missile shields of light water reactors, at enclosures of storage facilities and on instruments. Properly applied, seals assure that the equipment concerned has not been tampered with.

In nuclear plants there are also valves, tanks, pipelines, ports, openings, etc., which allow the non-routine transfer of such nuclear material in cases of emergency. From the point of view of safeguards, it is important to know that such non-routine transfer points have not been used by the operator for unrecorded flow of safeguarded material. Continuous surveillance at these points is not necessary. However, a "yes/no" answer to the question of whether radioactive material has passed through these non-routine transfer points is required.

An example of nuclear facilities having several non-routine transfer points, is the continuously refuelled CANDU-type power reactor, in which the remotely controlled routine flow of irradiated fuel bundles goes on behind heavy shields. Irradiated bundles are transferred from the reactor core, via the fuelling machine, discharge ports, elevators and under water trolleys to the spent fuel bay.

If one of the fuelling machine bundle magazines has a mechanical failure the operator can lock the machine at a check-out port or a service port. These ports are then used by the operator to check, maintain and eventually repair the fuelling machine. There are also ports which are used to introduce fresh fuel elements to the fuelling machine.

If the operator wants to divert irradiated bundles he only has to attach a shielded flask at such a port in the access area and push a bundle into the flask. The flask could then be transferred out of the plant through the air lock (Figure 1).

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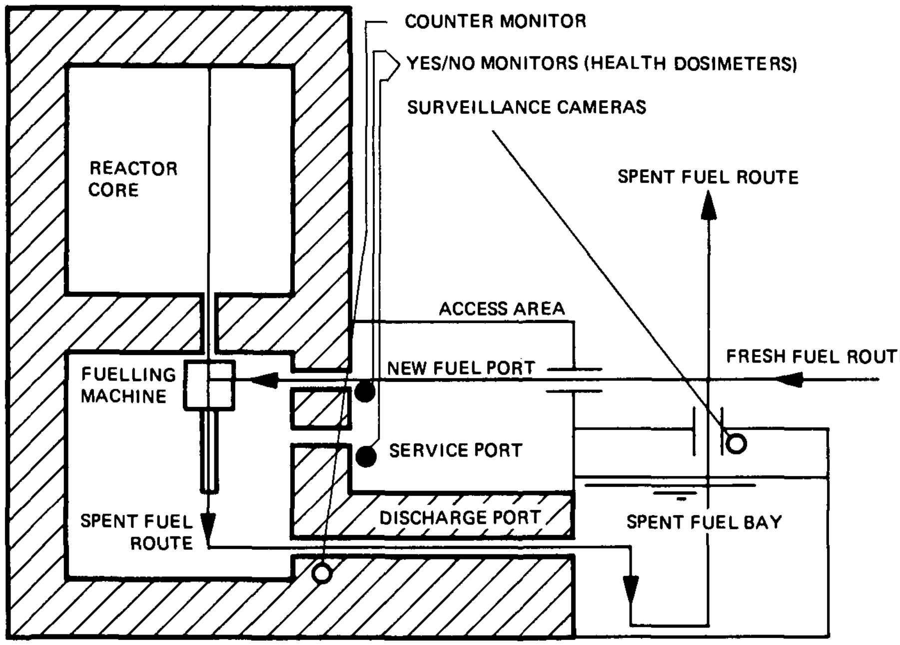

Figure 1: Example of use of health dosimeters as "yes/no" monitors in a CANDU-type nuclear power plant.

To detect such an operation, the IAEA has installed radiation measuring devices that were originally designed for medical use. These health dosimeters are packed inside seals near each check-out and service port. They serve as "yes/no" monitors of whether irradiated fuel bundles have passed through the ports. If an irradiated fuel bundle has passed through one of the ports, the adjacent dosimeter device records the resultant high dose. If no irradiated fuel bundle has passed through a port, the dosimeter device indicates only the much lower background radiation. The dosimeters are replaced by new ones during each routine inspection and the dosimeters are measured at IAEA Headquarters.

Specification of the dosimeters

The dosimeters to be used must satisfy the following conditions:

- Be sensitive to range of doses for monitoring irradiated fuel bundles between about 500 Röntgen (R) and 10 000 R;
- Be sensitive to range of doses affecting photographic films between 1 R and 100 R; and
- Be sufficiently small to be introduced in the IAEA seals.

In the light of these conditions, we decided to use radiophotoluminescent (RPL) glass dosimeters. When exposed to gamma radiation, the glass forms fluorescent centres which

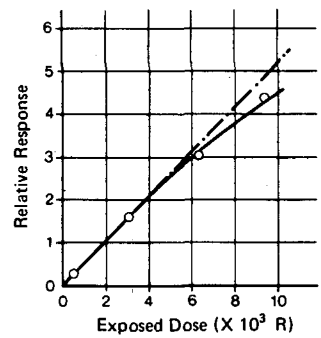

Figure 2: Response of glass-rod health dosimeter to gamma radiation from cobalt-60.

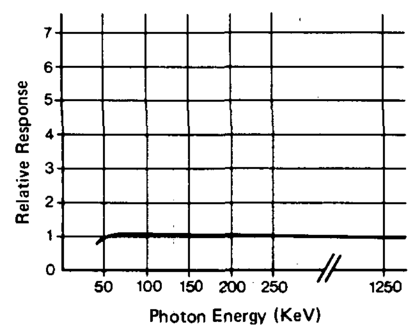

Figure 3: Energy response of dosimeter glass-rod encapsulated in a brass holder.

are long-lived because of their metastable state. If such an irradiated glass is illuminated with ultra-violet light in a dosimeter reader, an orange fluorescence is produced, the intensity of which is proportional to the absorbed dose.

We have chosen cylindrical Tosbiba glass rods, 1 mm in diameter and 6 mm in lenght, encapsulated in brass holders, about 2 mm in diameter and 11 mm in length. These glasses are composed of about 45% $LiPO_3$ and 45% Al $(PO_3)_3$ with Ag PO_3 and B_2O_3 as additives. This composition has a fading (change in relative fluorescence intensity) of a little as 1% per six months and an energy sensitivity range to gamma rays of between 50 KeV and about 2 MeV. This is just the range of most gammas emitted by the fission product in irradiated fuel elements.

Figure 2 shows the response linearity and Figure 3 the energy response of this glass dosimeter when encapsulated in brass holders.

Field tests

Field experiments of such "yes/no" monitors were carried out by IAEA inspectors in connection with their routine inspections of safeguarded facilities. One set of results of monitoring the transfer of irradiated fuel bundles through ports is given in Table 1.

Table 1: Radiation doses measured by "yes/no" monitors at both routine and non-routine transfer points at a CANDU-type nuclear power plant during a period of about 2 months.

Discharge Port (routine)	Check-Out Port (non-routine)	Service Port (non-routine)	New Fuel Port (non-routine)
10 000	4.0	13.3	5.2
10 000	11.2	2.2	3.7
7 520	3.3	7.4	6.4
10 000	9.6	1.8	1.7
12 800	7.8	3.2	2.2
8 640	8.9	3.8	2.0
300[a]			

[a] One bundle with an irradiation of about 3 800 MWd/t

It can be seen from the table that the passage of even a single bundle of irradiated fuel can be readily distinguished from normal background radiation.

Thus the field tests have demonstrated that the health devices can be used as "yes/no" monitors in safeguards applications.

Another application of such dosimeters has recently been introduced. Photographic surveillance cameras sometimes must be placed in areas where a relatively high background irradiation could occur under certain non-routine circumstances. Since the dose rate of such an irradiation as well as the sensitivity of the film to this dose rate were unknown, a dosimeter device is now installled inside the seal which secures the box of each of the cameras. If film damage does occur, the dosimeter will indicate whether or not the film damage could be due to irradiation. Other safeguards applications of the dosimeters are under study.