

Standardization of high doses in radiation processing

International co-operation in dosimetry is helping to promote quality assurance

by J.W. Nam

Ionizing radiation is an effective means to accelerate chemical reactions and improve quality of natural and synthetic material, preserve food, and sterilize medical products. Industrial application and advanced research of radiation processing today offers technological advantages, and recognition of its safety and economic importance is already being seen. In view of increasing trends in the use of high doses, it is necessary to standardize dosimetry worldwide, since quality assurance in radiation processing is primarily based on reliable dosimetry.

Timely initiation of the Agency's high-dose standardization programme made it possible to meet stringent demands for reliable and accurate dosimetry in high-dose applied research and radiation processing. The major objective of the programme is to organize dose standardization and assurance services on an international scale, and to promote dosimetry as a quality-control measure in radiation processing.

Since the initiation of this programme in 1977, an intensive emphasis has been put on the improvement of dosimetry systems and the development of new techniques. Several environmental factors can affect the response of dosimetry systems at high doses. These are carefully investigated. Dose intercomparison studies have been performed for the dose range from 10 gray (Gy) to 100 kGy with the active participation of 19 laboratories in 14 countries and one international organization. An extraordinary outcome of the programme has been a successful development of the electron-spin-resonance analysis of radiation-induced free radicals in alanine — alanine/ESR dosimetry — which has been developed for high-doses by the Gesellschaft für Strahlen- und Umweltforschung München (GSF), Federal Republic of Germany.

Mr Nam is a staff member in the dosimetry section of the IAEA's Division of Life Sciences.

In order to execute a concerted international effort to achieve measurement standardization of dosimetry and dose assurance for large radiation sources, the International Dose Assurance Service (IDAS) was launched in 1985 as an important service within the framework of the IAEA's high-dose standardization programme. It is envisaged that IDAS results can be used for confirmation of dosimetry, as well as quality control of radiation technology. Furthermore, the standardization of dosimetry provides a justification for the regulatory approval of irradiated products and the basis of international clearance for free trade. IDAS could become a milestone for further improvement of quality assurance for high-dose applied research and radiation processing.

Research and related activities

A total of 39 research activities on high-dose dosimetry, including 15 individual research and 2 co-ordinated research programmes with 24 research activities, have been supported by the Agency since the initiation of the high-dose dosimetry programme. Major accomplishments of the co-ordinated research programme include:

- Selection of alanine/ESR systems as the reference transfer dosimeter;
- Improvement of reliability and development of techniques of the dosimetry systems which were used in the intercomparison studies;
- Determination of the effect and correction for the unavoidable influences of environmental factors on the dose evaluation (e.g. temperature, humidity, climate, light, instabilities);
- Improvement of dose calibration and intercomparison procedures; and
- Design of standardized calibration apparatus and procedures.

Following the increasing demand for reliable dosimetry, the Agency organized the first international symposium on high-dose dosimetry in Vienna in 1984 to provide a forum for presentation and discussion of up-to-date developments in this fast moving field. The second symposium is planned to be held in Vienna at the IAEA in 1990. It is hoped that it will stimulate the international exchange of information and ideas and may lead to new or improved solutions to dosimetry problems of common concern.

Selection of alanine/ESR

Throughout a series of dose intercomparison studies with several candidate dosimeters, the alanine/ESR system was found to be the most appropriate one. It has shown consistent and stable behaviour to cover the entire dose range of gamma radiation for 10 Gy to 100 kGy for radiation processing practices. The stability of the free radicals in alanine is excellent because of their stable properties. This is reflected in a very small signal change with different storage conditions. The readout method does not require any chemical manipulation, nor any physical contact with the sample. The samples have archival properties for dosimetry as the ESR analysis is non-destructive. The precision of the readout can be possibly improved with the design of a more stable ESR spectrometer and with the cavity possessing a more uniform magnetic field distribution. Hitherto, achieved precision is better than 1.0%. The alanine/ESR system has the potential of being extended to lower doses, perhaps as low as a few Gy and may benefit from the development of more simplified readout equipment. Long-term emphasis on the dosimeter sample production, which is from pro-analysis material without the need of activators, has revealed excellent values of interspecimen scattering as well as interbatch uniformity. The dosimeter samples designed and produced at GSF show excellent performance, even under unusual environmental conditions.

To accomplish the goal of the programme successfully, the selection of internationally acceptable standard transfer systems are essential, against which routine dosimeters can be regularly checked, to provide accurate intercomparable dose measurements. The successful operation of a reference service on a worldwide scale makes heavy demands on the performance of the dosimetry systems. They must have a high level of pre- and post-irradiation stability to be reliable over a period of some months, and have freedom from, or the ability to correct for, environmental effects. The selection based on these criteria has led to the exclusion of systems otherwise acceptable under laboratory and facility conditions or under a more limited dose range.

Taking into account the conditions necessary to be a reference standard dosimeter, the Agency has decided to use the alanine/ESR system for the international service project. As a result of a pilot service project with 15 selected facilities in different geographic locations, the need for the international service was demonstrated. No organizational problems involved in its operation, or in the behaviour of the alanine/ESR system under practical conditions, have been found.

The IDAS programme

IDAS is provided on the basis of an "Agreement concerning the provision of a dose assurance service by the IAEA to irradiation facilities in its Member States" which entered into force on 12 July 1985. The operation of the alanine/ESR reference laboratory is executed under a contract between the Agency and GSF. Commercial and non-commercial irradiation facilities, as well as high-dose applied research institutes dealing with gamma and electron doses extending from 10 Gy to 100 kGy, are invited to participate in the service. Member States of the Agency are asked to designate the irradiation facilities for participation in the service and to indicate acceptance of the agreement.

For each participating facility, the Agency requests that technical information and data relevant to the service's provision is provided with notification of participation. Designated facilities, however, may be screened due to limited capacity of the service. Following receipt of notification for participation, the particulars of the appropriate service for each participating facility are determined, and the required number of dosimeters are mailed to the facility in accordance with an agreed schedule. All necessary information regarding irradiation of dosimeters is returned to the evaluating laboratory in detail. For one dose check service, a dosimeter package contains the three alanine capsules (1 control and 2 for irradiation) with a temperature indicator.

The evaluated result is communicated, with a certification, to the respective facilities within a period not exceeding 20 days after receipt of the relevant irradiated dosimeters at the reference laboratory. Participants irradiate the two reference standard capsules simultaneously with their own dosimeter for each dose of interest at arbitrary conditions. All data which the participating facility communicates to the Agency for provision of the service is kept in confidence. In particular, the results of the service are kept confidential and are not published or otherwise made known to unauthorized persons.

After 18 months of cost-free service, provided so that interested facilities may better test its usefulness, the Agency announced the need to charge for dose check services after 1987. This charge was determined at

US \$100 per dose check and is billed to each participant directly towards the end of the year for the total number of dose checks ordered. (Payment is made upon receipt of the invoice in US dollars, or by using the equivalent in UNESCO coupons.) Participating facilities are thus requested to bear their share of immediate expenditures incurred by the Agency for the provision of the service.

Indications of progress

In the 3 years IDAS has been in operation, more than 250 dose checks have been performed for a total of 27 facilities in which 18 countries participated. The maximum percentage deviations spread are remarkably improved from $-29\% \sim +24\%$ to $-15\% \sim +19\%$. For 1987, the deviations of within $\pm 5\%$ of a total dose checked are 51%, and that of within $\pm 10\%$ are shown to be as high as 86% respectively.

IDAS is intended to promote safety and economy, and facilitate quality assurance. Hence, it allows for the international trade of irradiated goods since legal and quality assurance requirements are most readily met by reliable dosimetry. It is not intended to license such trade, or to form a sole or exclusive basis for regulatory authorization. IDAS assures the accuracy of dosimeters used in irradiation facilities. It does not assure that a particular product has absorbed a particular dose.

The initiation of IDAS has met with positive response from many Member States. The service has been well accepted by participants, and no problems have arisen on either organizational or technical aspects. IDAS has grown to become one of the important ways the Agency contributes towards improving the quality of dosimetry in the irradiation industry and scientific world. In 3 years of service experience, it has been realized that IDAS has a potential contribution to quality control of radiation processing as well as calibration of dosimeters.

It can be noted that the more indirect stimulation of radiation processing dosimetry is to be found in the fact that the requests from irradiation facilities to standard laboratories for calibration control of dose measurements are increasing. A number of institutes scattered around the world are actively involved in establishing the measurement equipment and technology necessary to be able to carry out dosimetry using the alanine/ESR system. It has already been recognized as the best among those presently applicable techniques for routine and reference dosimetry, and it can be an important tool for reliable dosimetry until new techniques become available in the future.

For the worldwide standardization of high doses, the programme could be further developed and promoted to meet the stringent requirements for quality assurance in high-dose applied research and radiation processing industry.

