SUMMARY OF AN IAEA EDUCATIONAL SEMINAR AT KARLSRUHE, FRG, 14–18 APRIL

The Seminar on "The Uses of Californium 252 in Teaching and Research" was attended by 32 participants and 2 observers representing 23 countries. Twenty-four papers were presented in the formal sessions and panel discussions.

Californium-252

This meeting constituted the third phase of a project initiated by the Dosimetry Section of the IAEA in 1973. The first step, early in 1973, consisted of the development of a programme for the loan of Cf-252 sources to the Member States in support of education, training and some limited research. To date, 14 institutions in 13 Member States have participated in this loan programme.

In August last year, the Agency published an instructional syllabus and laboratory manual authored by Professors Eric J. Hall and Harald H. Rossi of Columbia University (Californium-252 in Teaching and Research, Technical Reports Series No. 159). The appearance of this publication, including guidance on the design and construction of a storage and use facility, was the second phase of this programme aimed at providing some support to potential users in the fields of radiation biology and dosimetry.

The objective of the programme's third phase – the convening of an Educational Seminar – was to provide a forum to bring together participants in the Agency's loan programme and experts in various scientific fields. Specifically, the Seminar consisted of a series of expert presentations in spectrometry, activation and prompt gamma analyses, on-stream analysis, dosimetry, health physics, radiology and radiotherapy.

PHYSICAL PROPERTIES AND USES

An essential feature in cross-section measurements and dosimetry is an accurate appreciation of the neutron energy flux density spectrum. The Cf-252 fission neutron spectrum and the use of Cf-252 sources to examine neutron cross-sections by neutron spectrum measurements was discussed. The results indicate that errors in some cross-sections are detectable which are considerably smaller than the accuracy of direct cross-section determinations.

A major application being studied is the use of Cf-252 sources in industrial processing by on-stream neutron activation analysis. An account of a pilot investigation for mineral processing was presented; the technique employed an irradiation loop capable of continuously exposing liquids to a one mg Cf-252 source. Various flow strategies were developed for a number of process-control studies and the specific example of an analysis for vanadium in crude oil was given.

A more general discussion of neutron activation analysis was presented, reviewing such factors as geometry, shielding and the engineering of facilities. A rather large irradiation complex employing an array of sources arranged concentrically about the irradiation volume has been in use at the National Bureau of Standards in Washington; practical problems such as well-logging, analysis of lead in house paints and other field applications have been examined at the NBS facility.

DOSIMETRY AND RADIATION PROTECTION

A series of talks was given, devoted to free-air and in-phantom dosimetry and dosimetric instrumentation. This survey began with a discussion of general principles and philosophies with a view to cataloguing the dependant and independant variables associated with dosimetry measurements and analysis, the critical experimental parameters and the fundamental techniques involved.

Dosimetry is associated with a variety of quantities and units beginning with source activity, field measurements such as energy flux density and fluence and interaction quantities such as absorbed dose and kerma. Thus, there are numerous calculational and instrumental problems associated with an accurate characterization of a mixed-field source. The radiation field of a Cf-252 source in free space is described in terms of kerma, absorbed dose and dose equivalent with respect to dose measurements for radiation protection purposes. Fluence and dose measurements have been made with activation, threshold detectors and high sensitivity doserate meters around radionuclide handling facilities. Track etching detectors and albedo neutron detectors for personnel monitoring have been developed and were discussed in detail.

The problems associated with in-phantom dosimetry are more critical due to exacting accuracy and precision requirements. Generally, ionization measurements have been preferred because of the assumed superior accuracy and precision over other techniques. However, the complexity of ionization methods coupled with inherent geometric limitations has led to the development of other technologies such as track-etching, thermo-luminescence dosimetry and calculational models.

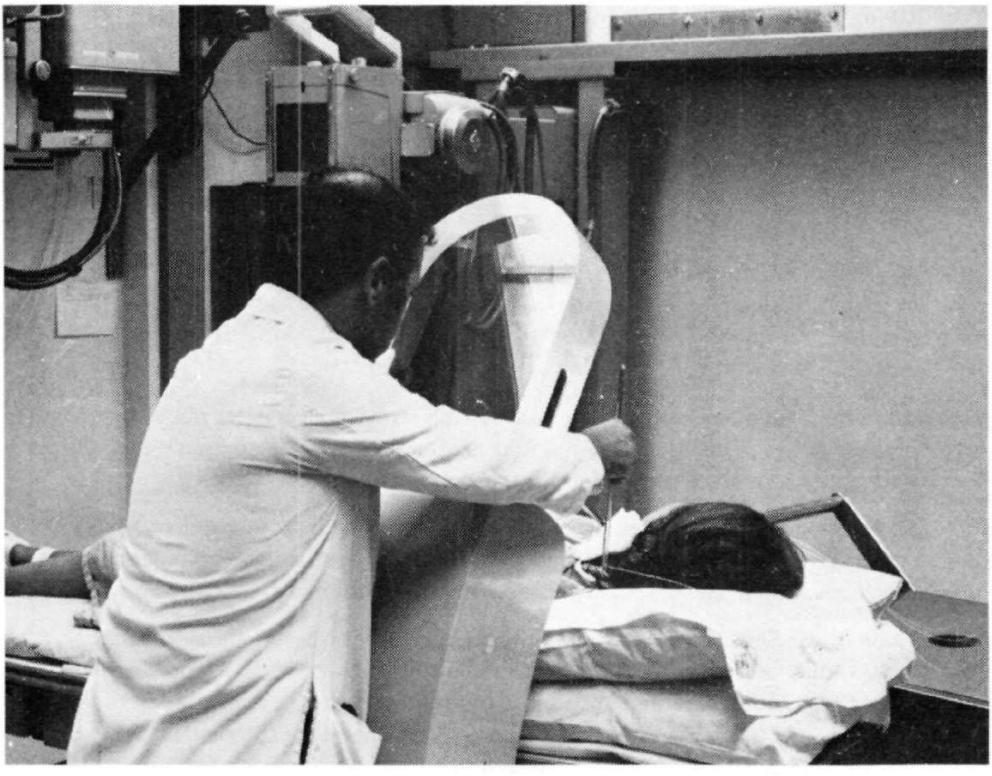
Radiation protection in the handling of fission neutron sources was stressed and reflects the growing concern over the hazards posed by such nuclides. The advent of medical neutron sources for radiotherapy studies has necessitated changes in the normal protection and monitoring procedures. Problems of storage, source preparation, transportation, application of sources into patients and allied subjects were discussed. Special attention was given to shielding measurements and calculations.

RADIATION BIOLOGY AND MEDICAL APPLICATIONS

The radiobiology of Cf-252 has excited some interest during the last few years as a result of the availability of brachytherapy sources for clinical radiotherapy studies. A review analysis of the relative biological effectiveness of Cf-252 was given, with emphasis on the interdependence of survival curve shape, total dose, dose-rate and type of biological system.

This apparent discrepancy of published relative biological effect (RBE) values can be explained as a result of the strong inter-relationship between dose-rate and the repair of sublethal damage. At high dose-rates with common radiations, sublethal repair is reduced, thereby effectively lowering the RBE relative to neutron exposure.

Also important is the oxygen effect. The existence of poorly oxygenated radio-resistant cells in solid tumour interiors is cited as a rationale for using neutron sources. Such sources have a lower oxygen enhancement ratio (OER) than comon radiations and are correspondingly expected to be more efficacious. Again, the dependence of OER on total dose, dose-rate and other modyfying factors must be understood.



Protective shields are used by medical staff in the clinical application of Californium-252.
Photo: Dr. Basil Hilaris, Memorial Hospital, New York.

In the clinical case, theoretical considerations are subject to modifications of numerous medical factors. Firtstly, the use of an experimental regimen must be prompted by compelling clinical arguments where the prognosis with normal treatments is poor. This fact greatly restricts the scope of any study. Compounded with the severe radioprotection restrictions in effect for the handling of Cf-252 sources, trials have proceeded under precautions unnecessary with radium or iridium implants.

A technique based on that used in Iridium-192 wire implants at Oxford was developed for the Cf-252 clinical trials: an after-loading procedure was used whereby the sources were loaded into surgically implanted plastic tubes. So far, since mid-1972, only 21 patients have been treated, making firm intercomparisons with other regimens not possible.

EDUCATIONAL AND RESEARCH PROGRAMME

A wide range of educational and research programmes were outlined, including:

- Two IAEA loan agreements with the Bahbha Atomic Research Centre in Bombay have provided sources for teaching and research. The scope of the work includes ionization, chemical, film and thermoluminescence dosimetry, activation and threshold analysis, and neutron spectroscopy.

- Following the construction of a prototype container, sources and some instrumentation were loaned to the Ghana Atomic Energy Commission. The programme in Ghana emphasizes dosimetry employing the dual ionization technique and foil activation.

- A sophisticated educational and research programme at the National Institute of Radiological Sciences in Japan employs nuclear studies, proportional counter measurements and radiobiological investigations.

- The research in progress at Groote Schuur Hospital and the University of Cape Town using IAEA supplied sources was reviewed. Investigations in a tissue equivalent phantom using a scintillation detector and employing pulse shape discrimination to separate the neutron and gamma components of dose were described. RBE and OER studies are also being pursued.

- A series of undergraduate experiments at the University of Neuchâtel was summarized. An air-alcohol diffusion cloud chamber, liquid scintillation detector and nuclear emulsion formed the bulk of the instrumentation for the experimental programme.

- Two papers dealing with the use of Cf-252 in the teaching of radiochemistry were presented, and an inexpensive facility used to introduce undergraduates to practical work on neutron activation analysis, radioactive decay and saturation was described.

- A session of the Seminar was devoted to papers on recent research developments. Preliminary studies associated with the development of a helium-jet transport technique applied to a Cf-252 source at the temperature of liquid air, and the construction of an activation facility at Kossuth University in Hungary designed to accommodate up to 50 mg of Cf-252 were described. Cross-section measurements, determination of titanium in bauxite and the use of track-etching detectors were also discussed.

CONCLUSIONS

It was generally agreed that small Cf-252 sources constituted a useful facility for pedagogic purposes. The high specific activity of these fission sources in association with relatively low levels of gamma contamination, compared with compound sources, gave Cf-252 a decided advantage over other types of neutron generators. Relatively low procurement costs, ease of handling, simplified packaging and a well-defined spectrum were cited as favourable indicators.

In industry, the use of Cf-252 in on-stream analysis and radiography appears promising and numerous national laboratories have instituted developmental programmes with applications in process quality control.

Medical applications are limited at present, owing to the necessity for a conservative philosophy in the design of clinical studies. The need to obviate the health hazards associated with exposure to neutrons and the relatively limited number of tumours which can be selected for treatment indicate a protacted period of assessment for medical uses of Cf-252 in brachytherapy.