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Extension of calibration facilities at the IAEA Laboratory in Seibesrdorf (credit: L. Czap/IAEA).

From the editor

This issue of the SSDL Newsletter starts with a brief review of changes of air-kerma standards of the BIPM and primary standards dosimetry laboratories, and their implications for IAEA calibrations. The IAEA policy on implementing changes in its radiation standards is spelled out in the report. SSDL members are advised to adopt a documented policy on the way to implement changes in their reference standards and on the process of communicating the impact of the changes to their end-users.

The second article is a report on the second research coordination meeting on the Coordinated Research Project E2.40.12, which deals with the development of TLD-based quality audits for radiotherapy dosimetry in non-reference conditions.

The secretariat of the IAEA/WHO SSDL network is pleased to inform its members about the extension of its calibration facilities in Seibersdorf. The new facilities will host a new therapy level ^{60}Co unit and an X-ray machine for diagnostic x-ray calibrations. The existing facilities will be devoted to radiation protection level calibration and training of IAEA sponsored fellows. The construction of the new facilities will be completed by the end of this year.

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SERVICES PROVIDED BY THE IAEA PROGRAMME IN DOSIMETRY AND MEDICAL RADIATION PHYSICS

The IAEA's Dosimetry and Medical Radiation Physics programme is focused on services provided to Member States through the IAEA/WHO SSDL Network and a system of dose quality audits. The measurement standards of Member States are calibrated, free of charge, at the IAEA's dosimetry laboratory. The audits are performed through the IAEA/WHO TLD postal dose assurance service for SSDLs and radiotherapy centres, and the International Dose Assurance Service (IDAS) for SSDLs and radiation processing facilities, mainly for food-irradiation and sterilisation of medical products.

The IAEA Calibration and Measurement Capabilities (CMCs) have been reviewed and published in the CIPM's (Comité International des Poids et Mesures) Appendix C. Additional information can be found at the web site: http://kcdb.bipm.org/AppendixC/search.asp?met=RI

The range of services is listed below.

Services	Radiation quality
Calibration of ionization chambers (radiotherapy, diagnostic radiology including mammography and radiation protection, including environmental dose level).	x-rays (10-300kV) and gamma rays from ^{137}Cs and ^{60}Co
Calibration of well-type ionization chambers for Low Dose Rate (LDR) brachytherapy.	γ-rays from ^{137}Cs
Comparison of therapy level ionization chamber calibrations (for SSDLs).	γ-rays from ^{60}Co
TLD dose quality audits for external radiotherapy beams for SSDLs and hospitals.	γ-rays from ^{60}Co and high energy x-ray beams
TLD dose quality audits for radiation protection for SSDLs.	γ-rays from ^{137}Cs
ESR-alanine dose quality audits for radiation processing (for SSDLs and industrial facilities), through International Dose Assurance Service (IDAS).	γ-rays from ^{60}Co, dose range: 0.1-100 kGy
Reference irradiations to dosimeters for radiation protection (for IAEA internal use).	x-rays (40-300 kV) and γ rays from ^{137}Cs and ^{60}Co

Member States who are interested in these services should contact the IAEA/WHO SSDL Network Secretariat for further details, at the address provided below. Additional information is also available through the Internet at the web site: http://www-naweb.iaea.org/nahu/dmrp/ssdl.asp

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Changes to the air-kerma standards of the BIPM and primary standards dosimetry laboratories: implications for IAEA calibrations to SSDL members

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P.J. Allisy-Roberts, BIPM
H.M. Kramer, PTB

Worldwide alterations in air-kerma standards have taken place in the past. For example, national air-kerma standards were changed in the late eighties by about 1% due to changes in the internationally agreed underlying physical data. More recently, several Primary Standards Dosimetry Laboratories (PSDLs) have altered their primary standards of air kerma. This paper reviews these changes and the implications for the air-kerma standards maintained by the IAEA.

The changes in air-kerma standards have impacted standards for several types of measurement situations. For ^{60}Co and ^{137}Cs gamma rays, a significant increase (about 0.8%) was implemented by many PSDLs [1] following a re-evaluation of the correction factors for wall effects and axial non-uniformity for cavity ionization chambers used in the realization of their air- kerma standards. For kilovoltage x-rays, recent developments in Monte Carlo techniques and spectrometry for the determination of correction factors for free-air chambers have also resulted in changes to the primary air-kerma standards for x-rays [2]. The aim of this technical note is to review the changes made by these PSDLS and to inform the IAEA/WHO Secondary Standards Dosimetry Laboratories (SSDL) members on the implications of these changes for calibrations provided by the IAEA. It should be noted that the absorbed dose to water standards have not changed.

1. IAEA Policy on Implementing Changes in its Radiation Standards

The IAEA maintains reference standards for radiation measurement that are directly traceable to the standards of the Bureau International des Poids et Mesures (BIPM) or to those of other primary laboratories. For example, the Agency's air-kerma standards, which are used in radiotherapy dosimetry, are traceable to the standards of the BIPM. On the other hand, for radiation protection dosimetry and Mo/Mo mammography beams, the IAEA standards are traceable to those of the Physikalisch-Technische Bundesanstalt (PTB). Finally, in the case of Rh mammography beams and ^{137}Cs low dose rate brachytherapy, the IAEA standards are traceable to the National Institute for Science and Technology (NIST) standards. Hence, in order to understand the impact on the Agency's calibration services of changes made in any of the primary standards, it is necessary to be aware of the source of traceability of our standards.

Usually, PSDLS communicate changes in their primary standards to the scientific community through peer-reviewed articles, letters to the editor or technical notes published in scientific journals. In general, the IAEA's policy is to review the declared changes in the primary standards for radiation measurement in order to understand the potential impact that would result when the IAEA standards are re-calibrated and to publish IAEA recommendations concerning the changes in the standards to SSDL members through the Newsletter. This policy is documented in the peer-reviewed IAEA quality system [3].

As a rule, when the BIPM/PSDLs change their primary standards, the IAEA does not make corrections to the calibration coefficients of its reference standards. Instead, we wait until the next occasion when our reference standards are to be calibrated by the BIPM/PSDL. At that time, the effects of the changes in primary standards are automatically incorporated into the new calibration coefficients. Obviously, the reference standards of SSDLs and hospitals that are calibrated at the IAEA using the new calibration coefficients for our reference instruments will be traceable automatically to the new primary standards. In this case, the IAEA notifies each end-user institution individually of the changes. An exception to this general rule concerns the change in the air-kerma standard for the ^{137}Cs low dose rate brachytherapy sources calibrated at the NIST as discussed in Section 4.

SSDLs are advised to adopt a documented policy on the way to implement changes in their reference standards as

a consequence of changes in the primary standards, and on the process of communicating the impact to their end-users.

2. BIPM

The change to the BIPM primary air-kerma standard for both low and medium energy x-ray beams was implemented in October 2003 [2]. The last time the BIPM calibrated the IAEA reference standards used in x-ray beams was during July-August 2004. The IAEA began to disseminate these new standards in October 2004. For a reference standard calibrated at the BIPM before October 2003, the ratio of its new calibration coefficient ($N_{K_a}^{new}$) to the old one ($N_{K_a}^{old}$) is given in tables 1 and 2.

Excluding the 10 kV beam quality (see * at the bottom of table 1), the change is within the expected variation of the IAEA reference standard. Thus, it was decided to maintain Agency policy and not to correct the calibration coefficients of the IAEA reference standards for the changes in the BIPM standards until the re-calibration of our reference instruments at the BIPM in October 2004.

No changes have been made to the air-kerma standards for ^{60}Co and ^{137}Cs gamma rays at the BIPM, although the work that is currently being conducted there will result in a change in the near future.

Table 1. Changes in the primary standards for low-energy x-rays at the BIPM (adapted from [2]).

Radiation quality	*10 kV**	*25 kV*	*30 kV*	*50 kVb***	*50 kVa***
$N_{K_a}^{new} / N_{K_a}^{old}$	*0.9970*	*0.9985*	*0.9987*	*0.9991*	*0.9993*

* The IAEA does not provide calibrations at 10 kV.

** By convention, the more penetrating 50 kV x-ray quality is referred to as 50 kVa and the less penetrating as 50 kVb.

Table 2. Changes in the primary standards for medium energy x-rays at the BIPM (adapted from [2]

Radiation quality	*100 kV*	*135 kV*	*180 kV*	*250 kV*
$N_{K_a}^{new} / N_{K_a}^{old}$	*0.9989*	*0.9982*	*0.9982*	*0.9999*

3. PTB

On January 1, 2002 the PTB implemented changes to its primary air-kerma standards for ^{60}Co and ^{137}Cs gamma ray beams. The calibration coefficients were increased by 0.95% and 0.85% in ^{60}Co and ^{137}Cs gamma ray beams, respectively [4,5]. The IAEA had its air-kerma reference standards used in ^{60}Co and ^{137}Cs gamma ray beams calibrated at the PTB in June 2001 just prior to the change in the PTB standards. The IAEA re-calibrated its reference standards at the PTB in July 2005 and is expecting to disseminate the new standards by January 2006. In view of the accuracy requirements in radiation protection calibrations, it was decided to continue with the Agency policy and not to correct the PTB calibration coefficients of the IAEA reference standards currently in use but to wait until January 2006 to implement the changes.

For an SSDL reference standard calibrated at the IAEA after January 2006, the new IAEA air-kerma calibration coefficients are expected to change by the factors given in table 3. The SSDLs should be aware of these changes. Concerning calibration coefficients issued prior to January 2006 by the IAEA in ^{60}Co and ^{137}Cs gamma ray beams used in radiation protection, the IAEA encourages SSDLs to implement the changes through a well specified procedure.

Please note that Table 3 is also applicable to the operational radiation protection quantities derived from air kerma and the use of conversion coefficients as given in ISO 4037-3 [6].

The primary air-kerma standards at PTB for x-ray beams have not changed.

Table 3. Changes in the primary standards for ^{60}Co and ^{137}Cs gamma rays at the PTB [4,5].

Radiation quality	$N_{K_a}^{new} / N_{K_a}^{old}$
X-rays	*1*
^{137}Cs	*1.0085*
^{60}Co	*1.0095*

4. NIST

The NIST standards for air kerma (and exposure) for gamma rays were changed on 1 July 2003. The change reported for ^{137}Cs beams applies also to the historical NIST primary standard for ^{137}Cs brachytherapy sources, as the primary standard for this source was established using the same graphite-walled, Bragg-Gray ionization chambers. The IAEA calibrated its brachytherapy well type chamber at NIST in 1999. Since we do not intend to seek recalibration of the IAEA standard in the near future, we have made an exception to our usual approach. Without re-calibrating the IAEA standard, we altered its calibration coefficient to be consistent with the new standard of the NIST and we began to disseminate it on 1 January 2005. Thus, for well-type ionization chambers calibrated at the IAEA prior to January 2005, the reference air kerma or air-kerma strength should be multiplied by 1.0090 to account for the change in the NIST standard.

No changes have been made to the calibration standards for Rh mammography x-ray beams at the NIST.

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Report of the Second Research Coordination Meeting (RC-885.2) on the CRP E2 40 12

Development of TLD-based Quality Audits for Radiotherapy Dosimetry in Non-Reference Conditions

4 – 8 October 2004, IAEA Headquarters, Vienna

CRP Participants: M. Arib (Algeria), F. Garcia Yip (Cuba), M. Saravi (Argentina), A.K. Mahant (India), D. Georg (Austria), D. Thwaites (UK), K. Sergieva (Bulgaria), W. Bulski (Poland), K. Li (China)

Scientific Secretary: J. Iżewska

A. Background

The objective of the CRP E2.40.12 "Development of TLD-based quality audits for radiotherapy dosimetry in non-reference conditions", is to assist the participating Member States in developing thermoluminescent dosimetry (TLD) based quality audits for radiotherapy dosimetry in non-reference conditions. The participants of the CRP E2.40.12 are the External Audit Groups (EAG) of Algeria, Argentina, Bulgaria, China, Cuba, India, and Poland. Support to the CRP is given by Austria and ESTRO[1] through research agreements.

A three level flexible TLD audit system was developed to allow the experience gained from preceding audit levels to be incorporated into subsequent audit steps:

- Step 1. Postal dose audits for photon beams in reference conditions. It is necessary for any postal audit system to implement this step before launching a subsequent audit level.
- Step 2. Postal dose audits for photon and electron beams in reference and non-reference conditions on the beam axis. This includes checks of beam output, dose variation with field size and shape, and wedge transmission for photon beams; and checks of electron beam output, as well as dose variation with field size and treatment distance.
- Step 3. Audits for photon beams in reference and non-reference conditions off-axis. This includes checks of beam profiles, with and without wedges, for symmetric and asymmetric fields for photon beams.

Based on the IAEA standard TLD holder for high-energy photon beams, a special TLD holder with a horizontal arm was developed that enables off-axis measurements. Three TLDs can be irradiated at a time, two off-axis TLDs placed at ±5 cm from the central TLD. New procedures were prepared for the TLD irradiation at hospitals. The off-axis measurement methodology for photon beams was tested in a multi-centre pilot study involving the participating countries.

Instructions and datasheets were prepared for TLD postal dose audits for Co-60 and high energy x-ray beams, in reference and non-reference conditions on- and off-axis, for symmetric fields. The relevant forms for electron beam audits, as developed by ESTRO, were reviewed by the CRP participants and, together with the documentation for photon beams, they are being adapted to local conditions and translated into the national languages of the CRP participants.

The contributions to the project by Austria and ESTRO have been significant, in terms of the conceptual development of systematic steps in national audit systems, development of the documentation and the testing of the new TLD methodology with practical measurements using clinical beams.

Given the importance of external audits for improving the standards in radiotherapy practice in Member States, the CRP E2.40.12 will continue until its planned completion in 2006.

[1] European Society for Therapeutic Radiology and Oncology

B. Discussions in the meeting

The meeting started with the opening address by the SH-DMRP. The first presentation, delivered by the Scientific Secretary, gave an overview of the progress in the CRP E2.40.12 with the focus on the research conducted under the CRP and the development of the methodology for TLD audits in non-reference conditions. It was followed by a presentation of the results of the EQUAL (ESTRO QUALity Assurance Network) TLD network operating in the European Union, which conducts TLD dose audits in reference and non-reference conditions. The presentation was delivered by Dr. D. Thwaites.

A series of presentations on the research relevant to the CRP and future plans were given by the meeting participants. They described the situation in the individual countries with respect to the national QA programmes and the developments in the dosimetry audit systems. The status of the development of methodology and procedures for QA audits for radiotherapy hospitals in the participating countries was discussed with the focus on TLD measuring procedures. The participants are in different stages of the process of the adaptive research and some have already conducted pilot studies for the photon beam audits on-axis, in non-reference conditions.

Further discussions proceeded with the presentation by the Scientific Secretary of the results of a multi-centre pilot study of TLD measurements for photon beams off axis using the modified TLD holder with a horizontal arm, in which all EAGs participated. Correction factors required for the calculation of dose from the TLD readings were presented by Prof. D. Georg.

The working schedules for the countries were reviewed with regard to the subsequent implementation steps of the national QA programmes. In particular, the general procedure for photon beam checks in non-reference conditions on-axis has been developed and modifications for each country, depending on the local conditions, were discussed.

The last day of the meeting was dedicated to a visit to the Dosimetry Laboratory in Seibersdorf, where the participants familiarized themselves with the practical aspects of operation of the IAEA TLD system, its maintenance and the quality control procedures that are necessary to ensure high precision in TL-measurements.

C. Status Reports from the Participants

D. Thwaites, ESTRO

The ESTRO Quality Assurance network for radiotherapy (EQUAL) was set up in 1998 for the countries of the European Union. It was funded by a number of renewable grants from the European Union between 1998 and the end of 2003. From early 2004, the funding has stopped and EQUAL has had to move onto a self-financing basis, by setting charges for audits, which has necessitated a new administrative and legal structure. The EQUAL TLD postal dose service includes photon and electron beam checks in reference and non-reference conditions. By September 2004, the service has provided audits to more than 600 radiotherapy centres and checked about 3250 beams. Since 2002, this has included a service for checking MLC beams. Dosimetric problems in the beam calibration, errors in beam data used as input to the treatment planning system (TPS) and uncertainties in the algorithms used in the TPS can be detected in the EQUAL audit.

The participating centres are instructed to irradiate the TLD (LiF) capsules to a dose of 2 Gy based on calculations using the treatment planning system applied routinely in clinical use. For photon beams, seven dosimetric parameters are checked in a normal audit: the beam output in reference conditions, percentage depth doses, beam output variations for a number of open and wedged fields and the wedge transmission factor. Measurements with electron beams are carried out for 3 different field sizes and two source-skin distances (SSD). MLC measurements are carried out in 6 different shapes and sizes of fields.

About 20% of all beams had to be rechecked due to deviations larger than 5% in at least one of these parameters. In some of these cases the deviations could be traced to set-up errors or other mistakes at the time of the TLD irradiations, e.g., wrong source-skin distance, wedge forgotten, wrong depth. However approximately 4% of beams (2% of measurements) were shown to have deviations due to real dosimetry problems. Third checks or site visits were then offered, the latter having been carried out in 15 centres.

Most of the significant deviations in dose are for non-reference conditions. For the reference geometry the deviations have progressively decreased with time. Thus, the efforts in Europe, including the implementation of new dosimetry protocols and quality systems, training-courses by ESTRO, and the impact of the EQUAL and related audit programmes themselves have had a positive effect, showing the value of these activities.

The EQUAL programme has recently been extended to other modalities and facilities in developmental and pilot studies. An ESTRO project on brachytherapy dosimetry QA – BRAPHYQS – has developed phantoms and a methodology for mailed audits for geometric checks of brachytherapy source imaging and reconstruction, and also TLD audits of Ir-192 HDR brachytherapy dosimetry. So far 86 centres have been checked on the first of these, which is being offered as a routine audit, and a test round of 8 centres has piloted the second. In addition another ESTRO project on QA of intensity-modulated

beams – QASIMODO – has piloted film dosimetry methods between 16 centres to compare the delivery and verification of IMRT treatments in a mailable phantom representing a prostate treatment. This may form the basis of other related developmental projects and may also allow for transfer of knowledge and methods from the developmental group to the regular audit group as the basis of other possible routine audit services.

A brief summary was also given of the recent progress of the UK radiotherapy dosimetry audit network, a co-operative audit system co-ordinated in all UK radiotherapy centres by the IPEM (the UK Institute of Physics and Engineering in Medicine, the professional association of Medical Physicists in the UK). This has been running since the first comprehensive national dosimetry inter-comparisons took place in the late 1980s. It is based on a number of co-operative groups and all audits are by site visits and use ion chamber dosimetry. Most radiotherapy modalities have been considered, including high energy photon and electron beams, kV x-ray beams, brachytherapy source activities and dosimetry and geometric parameters on accelerators and simulators. A number of geometric and semi-anatomic phantoms have been developed to allow audits of realistic multi-field planned irradiations, with developments going on in some of the groups to widen the scope of audit to new technology and treatments. A recent pilot study was reported, undertaken in the Scottish+ group to assess the feasibility and the methodology for an on site audit of MLC dosimetry and also for *in vivo* audits directly on patients in different departments. These pilots were successful and will be extended to more centres in the near future.

M. Arib, Algeria

As a second step of the quality assurance programme for external radiotherapy set up at the Secondary Standards Dosimetry Laboratory of Algeria, a methodology for the audit of radiotherapy beams in non reference conditions on the beam axis has been successfully implemented. A feasibility study including 5 beams from four institutions was performed in 2002.

A first audit of all national radiotherapy beams was conducted in 2003, including 9 Cobalt-60 units and three accelerators. For two participating centres, three beam calibrations showed deviations outside the acceptance limit of 5 %. As a follow up action, a second audit was conducted to recheck the beams in question. The results have improved and the deviations were explained.

In 2004 a cross check using TLDs was undertaken with the IAEA and the EAGs from China, India, Malaysia and Argentina. All results were good, with the deviations between the stated and measured dose within 2.5%.

In order to implement the audit step 3 of photon beams in reference and non-reference conditions off-axis, the IAEA provided the members of the group with a new TLD holder with a horizontal arm allowing simultaneous irradiation of three capsules. Experimental work carried out in the Algerian SSDL showed no influence of each capsule over the others. The effect of the horizontal arm on the response of the TLDs was evaluated at three depths of 5 cm, 10 cm and 15 cm and the correction factors determined. The new holder was further tested for beam profiles with good agreement between the ionization chamber measurements and TLDs.

Years 2005 and 2006 will be dedicated to the study of the different effects (holder effect, energy dependence, effect of the horizontal arm, etc.) experimentally and by Monte Carlo simulation. A more sophisticated worksheet for the evaluation of the TLD will be designed and implemented. A pilot study for audit of electron beams and asymmetric fields will be undertaken.

To summarize, step 1 of the audit is fully implemented in Algeria and is carried out each year for all radiotherapy centers. Step 2 is implemented for photon beams and will be repeated in 2005. Step 3 (symmetric fields) will also be carried out in 2005. For electron beams, a pilot study will be performed in 2006 and will be carried out in the future between the two audits corresponding to steps 2 and 3. Regarding the asymmetric fields, a survey of radiotherapy centres will allow identification of the centres conducting this type of treatment, and depending on the survey results, a pilot study may be undertaken in 2006.

M. Saravi, Argentina

The EAG of Argentina has implemented the audit step 1 for photon beams in reference conditions for all hospitals and following the methodology of the audit step 2, conducted TLD runs of photon beams in non-reference conditions on-axis with several hospitals participating. In order to extend the TLD audits to electron beams, the response of TLDs against the various electron energies was studied. The energy correction factor was determined for beams of nominal energies 10, 12, 15 and 18 MeV. It ranged from 1.05 for the lowest to 1.02 for the highest energy beam.

As the TLD laboratory is undergoing an upgrading process, with a new automatic TLD reader installed, a system calibration is on-going and the relevant correction factors are being determined.

Forms to be filled-in by participants for dose audits in non-reference conditions were prepared following the recommendations given during the RCM held in 2002. On-site visits for the review of dosimetry practices have been conducted at three radiotherapy centres.

The programme for 2005-2006 will involve the continuation of audits for the step 1, beam output in reference conditions, high energy photons. The depth of measurement will change from 5 cm to 10 cm which requires the verification of the holder attenuation corrections. Audits

will be primarily directed to newly established radiotherapy centres.

Step 2 regarding TLD audits for photon beams in reference and non-reference conditions on the beam axis will be performed for open and wedged beams, for small and large radiation fields. Audits in reference and non-reference conditions on the beam axis will be performed for centres that have successfully completed the basic step 1. A pilot study for photon beams in reference and non reference conditions off-axis (step 3) will be carried out with 5 pilot centers for symmetric fields. For the step 3, asymmetric fields, the Argentinean EAG is ready to participate in a pilot study as scheduled by the IAEA.

Electron beam audits will be conducted on a pilot basis with 5 radiotherapy centres for two different fields and two different distances from the source.

The TLD audit programme in Argentina beyond 2006 will focus on the step 2 for high energy photon and electron beams and on the step 3 for symmetric fields for photon beams. The audits will be made with a frequency of 2 years for photons and electron beams, alternating between the step 2 and step 3 for photon beams. A survey will be made in order to determine how many centres are interested in the step 3 for asymmetric fields.

K. Sergieva, Bulgaria

The establishment an External Audit Group (EAG) relies on experienced medical physicists and radiation oncologists recommended by the Bulgarian Society of Biomedical Physics and Engineering and the Bulgarian Association of Radiology. The aim of the EAG is to ensure adequate precision in the dosimetry of clinical beams. The EAG has selected and suggested the most important parameters for quality control of treatment units taking into account the situation in radiotherapy departments in Bulgaria. Main activities are: organization of regular postal TLD audits of all photon beams in reference and non-reference conditions; on site measurements whenever a new installation is to be commissioned and then regular checks as a part of inspection; providing technical assistance and cooperation in the set-up of QA programmes; ascertaining the adequacy of QA at the radiotherapy department level and advising accordingly; developing, adapting and disseminating recommendations, codes of practice, regulations, standards etc., providing assistance in the analysis of the results of QA programmes; organizing training in QA; development and updating of national radiotherapy infrastructure database.

The feasibility study for Co-60 beam audit with TLDs was performed. The dosimetric parameters of interest were: the beam output in reference conditions, the dose at depths 10 cm and 20 cm for 7 x 7cm^2, 20 x 20 cm^2, 7 x 20 cm^2 fields; wedge transmission factor of 45˚ wedge. The instruction sheets, data sheets, discrepancy analysis forms and the results reporting form were developed as appropriate.

In 2005-2006 the Bulgarian EAG will undertake the following taks:

- verify the calibration of TLD system for Co-60 beam with the IAEA Dosimetry Laboratory using $N_{D,w}$ based methodology
- organize a pilot TLD run for hospitals for photon beams on-axis in non-reference conditions
- perform a feasibility study of the TLD holder with a horizontal arm for dose measurements in 3 – 5 Co-60 beams off-axis (symmetric open and wedged fields)
- adapt the instruction sheets, data sheets and results reporting forms for the photon beam audits in non-reference conditions
- perform the feasibility study of the TLD holder with a horizontal arm for dose measurements in 3 – 5 Co-60 beams off axis (asymmetric open and wedged fields).
- perform the feasibility study of electron beams in reference conditions
- organize a pilot TLD run for hospitals (3 – 5) photon beams off-axis in non-reference conditions (symmetric and asymmetric fields).

The frequency of the audit in non-reference conditions will follow the national survey to be conducted by the Bulgarian EAG.

K. Li, China

During 2003-2004, feasibility studies and related work on TLD-based quality audits for radiotherapy dosimetry in non-reference conditions were carried out by the Chinese EAG in a few focus areas outlined below.

In view of the fact that many hospitals located at border areas in China have never participated in international or national TLD audit activities, the TLD audits in reference conditions are of primary importance. A total number of 100 photon beams were checked through the IAEA/WHO TLD audit services. At the same time, the national EAG conducted national audit services in 6 provinces in China, and a total number of 100 photon beams were checked. For building the capacity of the EAG to provide dose audit to Chinese hospitals, the national TLD audits were run in parallel to those of the Agency's.

Verification of the EAG TLD system for Co-60 with the IAEA Dosimetry Laboratory showed the result of -1.7% for the deviation between the stated dose of the IAEA and the TLD dose, which is acceptable within the expected uncertainty of 3.5% of the Chinese TLD system.

The feasibility study for photon beams in reference and non-reference conditions on the beam axis using the new modified TLD holder was performed in a Co-60 beam,

and 6 MV and 15 MV high energy x-rays. The TLD results were generally within 3.5% compared to ion chamber measurements, except for the measurements at 20 cm depth in a water phantom for which the holder attenuation correction requires verification through more precise experiments. Instructions and data sheets for national TLD audits in non-reference conditions were developed following the lines of the related IAEA documents.

A feasibility study for high energy electron beams at the depth of dose maximum on the beam axis using the IAEA holder was carried out for 9 MeV and 16 MeV electron beams. The deviations between the reference dose values and TLD dose values were generally within 3.5%, although the calibration of the plane-parallel chamber requires verification.

Feasibility study for photon beams (open and wedged) off-axis using the new IAEA holder were carried out in a Co-60, 6 MV and 15 MV photon beams. Most results were within 3.5%.

Cross comparison with the Algerian EAG was conducted through TLD exchange, with the results in good agreement with those stated by the Algerian EAG.

In view of fact that a large number of radiotherapy machines are used in hospitals in China, adequate resources will be needed for implementing TLD audit services routinely over the country. The Ministry of Health in China has already recognized the importance of the audits in radiotherapy dosimetry and paid more attention to this work including the promotion of the CRP. It is hoped that a sub-EAG network in China will be set up soon after the completion of the CRP and the TLD audits will be implemented in all provinces on a regular basis. The audits of step 1 will be implemented with a frequency of 2 years. For steps 2 and 3, the frequencies will be three and five years respectively.

F. Garcia Yip, Cuba

During 2003-2004, a number of TLD capsules were interchanged between the Cuban SSDL and the IAEA Dosimetry Laboratory in the so called “blind tests” in order to verify the calibration of the Cuban TLD system for Co-60. The results of these checks were discussed.

At present, the Cuban SSDL uses TLD in the form of micro-rods. The plastic capsules for irradiation at radiotherapy levels are filled with 3 micro-rods each, providing 3 redundant readings from each capsule. It is recognized however, that the uncertainty this technique incorporates in the overall measurement is rather high due to differences in the amount of LiF in each individual micro-rod, which also varies with manipulation. To reduce the uncertainty (declared to be around 2.5%), the Cuban TLD laboratory will use TLD powder as of 2005.

The Cuban EAG has conducted a pilot study of the audit step 2 (non-reference conditions, on axis) that included five hospitals. This exercise is still open and not ready for publication.

A set of guidelines and forms were written in Spanish and positively evaluated by the participants from the hospitals (physicists and a radiographer). A member of the Cuban EAG participated in the testing of procedures in a pilot irradiation run of the audit step 3 (non-reference conditions, off-axis). TLD capsules were irradiated at the beam qualities of 6 MV and 25 MV. The results were evaluated at the IAEA Dosimetry Laboratory and presented at the RCM.

For the forthcoming years of this CRP (2005-2006) the Cuban EAG intends to include all Co-60 machines in a national TLD audit run covering steps 1-3. In the future, a 2 years auditing cycle will be established, alternating on-site visits with postal TLD audits.

A. K. Mahant, India

In continuation of the programme under the CRP, work was carried out by the SSDL-BARC involving the ongoing activities for national TLD audits in reference conditions and research related to audits in non-reference conditions. Two TLD quality audit runs were conducted for dose measurement in reference conditions with 93 participants in 2003. A TLD pilot study for non-reference conditions for photon beams on-axis was conducted, in which six institutions participated.

Calibration of the TLD reader was checked using TLDs irradiated at the IAEA to doses ranging from 1.5 to 2.5 Gy. One capsule was irradiated to a dose unknown to BARC. The BARC estimated dose was found to be in close agreement with the IAEA value (0.3%). A reciprocal TLD intercomparison was also taken up with the SSDL-Algeria. Estimated doses to the capsules irradiated in Algeria were evaluated and communicated to Algeria. Results from Algeria are awaited.

The EAG India participated in a multi-centre pilot study conducted by the IAEA on TLD quality audit in non-reference conditions for Co-60 and two high energy X-ray beams.

Future plans involve the continuation of a QA programme in reference conditions with the TLD placed at 10 cm depth. About 60 hospitals are expected to participate. Pilot studies will be conducted for photon beams in non-reference conditions, the step-2 and step-3, symmetric fields. Required instruction sheets and data sheets will be prepared. TLD audits of the steps 2 and 3 will alternate in different years, with about 50 hospitals/year participating.

W. Bulski, Poland

The radiotherapy infrastructure database for Poland has been updated by the national EAG. The database contains the up-to-date information on the numbers and technical data of radiotherapy equipment in Poland (both tele- and brachytherapy): radiotherapy machines, simulators, treatment planning systems, CT and MRI scanners,

dosimeters, phantoms, staffing (medical physicists). Such updating is done every year.

The instruction and data sheets for TLD audits in non-reference conditions on axis, which are sent out to participants together with the TLD capsules, have been revised, updated and finalized. They have been prepared for the audits of Co-60, photon and electron beams with the dose value stated by the participants on the basis of the treatment planning system (TPS) calculations.

The appropriate data sheets are being prepared for the audits in non-reference conditions off-axis with the dose value stated by the participants on the basis of the TPS calculations.

During the reporting period the following tasks have been performed:

- The TLD laboratory has been upgraded. The new automatic TLD reader has been commissioned and the characteristics of the new TL-powder batch have been thoroughly examined.
- A TLD audit in non-reference conditions for Co-60 beams has been performed for 9 volunteer centres (out of 19 radiotherapy centers in Poland).
- A TLD audit on axis in non-reference conditions for photon beams has been performed for 21 centres (all radiotherapy centres).
- A TLD audit in reference conditions for electron beams has been performed for 20 centres.
- A feasibility study of the audit in non-reference conditions off-axis has been performed.
- The TLD measurements in non-reference on axis give results which are comparable with previous audits in reference conditions (within ±3.5%).

The results of the postal audits in Poland were presented at the ESTRO Congress (Geneva 2003) and at the IOMP Congress (Syney 2003), as well as in a few publications.

The audits planned for the years 2005-2006 involve a TLD audit in non-reference conditions for Co-60 beams for the centres that did not take part in the previous year audit, a TLD audit in non-reference conditions in all centres for photon beams (2 beams per centre, for the beams that have not been audited so far), a pilot TLD audit off-axis (step 3) for both symmetric and asymmetric fields in 3-5 centres. The audits will continue in 2006 in non-reference conditions for electron beams and a pilot TLD audit asymmetric half blocked fields (asymmetric jaws) will be conducted in 3-5 centres. A methodology for the TLD audit for irregular fields is in preparation.

The recommendations on the upcoming audits in various non-reference conditions are going to be prepared along with the instructions and data sheets for the different types of audit runs.

Two audit runs per year are performed on a regular basis with virtually all Polish radiotherapy centers participating. The pilot studies might be combined with regular audit runs for on-axis checks. After 2006, the audit runs would be alternated between the step 2 and step 3 audits.

J. Izewska, Scientific Secretary, IAEA

Tests of a new TLD holder with the horizontal arm were conducted jointly by the IAEA and the AKH-Vienna. Five test sessions were run in 2002-2003 with high energy photon beams of Co-60, 6 MV, 10 MV and 25 MV available at AKH. TLDs were irradiated by the IAEA jointly with AKH staff and evaluated at the IAEA Dosimetry Laboratory in Seibersdorf.

The measurement programme was optimised resulting in the time required of about 2 hours per beam for both ion chamber measurements and TLD irradiations. The programme involves the irradiation of 11 TLDs in 10 x 10 cm^2 and 20 x 20 cm^2 open and wedged fields on- and off-axis at 10 cm depth in a water phantom. The values of the absorbed dose to water, in Gy, are determined from TLD readings at each of the 11 measurement points and relative values are derived, such as the output factors, wedge transmission factors and off-axis ratios. The TLD evaluation at the laboratory including the TLD readout and the calculation of doses and dose ratios from TLD readings requires about 1 day per beam. In this exercise the results of the dose measurements with TLD for open and wedged fields were, on average, within 1% compared to ionization chamber measurements. The results of relative measurements (output factors, wedge transmission factors, off-axis ratios) were also within 1% of the TLD to ionisation chamber determined values.

A multi-centre TLD pilot run organized in 2004 involved 7 radiotherapy centres with 20 high-energy photon beams (Co-60, 6 MV - 23 MV) in Argentina, Bulgaria, Cuba, China, Hungary, Poland and the EQUAL laboratory. Algeria and India joined the pilot exercise at a later stage. The TLDs, the new holders, and specially prepared instructions and data sheets were distributed to participants by mail. Upon the return of irradiated TLDs, they were evaluated by the IAEA Dosimetry Laboratory and the doses reported by the participants compared to TLD doses. The results were prepared in the form of an individual results certificate and distributed to the participants at the RCM together with the global results. The results of the dose measurements in terms of the ratios of the IAEA measured dose to the participant stated dose for all beams, at all measurement points were N = 203, mean = 0.999, std. dev. = 0.013. The results of the dose ratio measurements (the dose off-axis to the dose on-axis for open and wedged beams, D(20x20)/D(10x10), D_{wedge}/D_{open}) in terms of the ratios of the TLD measured value to the participant stated value for all beams and all parameters were N = 146, mean = 0.999, std. dev. = 0.012. As the results of the pilot run are very good, the methodology has proven to be feasible.

The pilot study of the modified TLD holder has been successfully completed and the methodology for dose

audits in non-reference conditions off-axis for photon beams including the relevant forms is ready for transfering to the national level. The expertise built-up in this exercise will be adapted by the national EAGs to the local conditions in each participating country.

D. Georg, Austria

After testing a prototype TLD holder with a horizontal arm with high energy photon beams in a variety of geometric conditions at the AKH, Vienna, the scope of the work performed was the determination of a set of corrections for the TLD holder.

The perturbation correction factor accounting for the attenuation of a photon beam by the holder tube is required to be applied in the dose calculation from the TLD readings. The holder correction is defined as the ratio of the dose with no holder in the photon beam to the dose with the holder. The measurements were performed with and without the holder horizontal arm in place. The perturbation measurements were performed first with a Farmer type chamber of 0.6 cm^3 in photon beams of Co-60, 6 MV, 10 MV and 25 MV at 10 cm depth for field sizes of 10 x 10 cm^2 and 20 x 20 cm^2 open and wedged (60° wedge), and repeated with 0.3 cm^3 and 0.015 cm^3 ionization chambers.

The shielding of the TL-powder by the holder tube was derived from measurements performed with ionisation chambers of 0.6 cm^3 and 0.3 cm^3 volumes. The interpolation of the two chamber readings was made according to the ratios of the shielded volume to the total volume V_{sh}/V_{tot} for the chambers and the TL-detector. These ratios, as adapted from an earlier study, are 0.215 for the TLD, 0.292 for the 0.3cm^3 and 0.192 for the 0.6 cm^3 volume chambers. The resulting holder correction factor at 10 cm holder tube length was 1.018 for Co-60, 1.012 for 6 MV, 1.009 for 10 MV, and 1.006 for 25 MV photon beams for a holder without the horizontal arm. When the horizontal arm was added, the attenuation correction changed to 1.017 for Co-60, 1.013 for 6 MV, 1.012 for 10 MV, and 1.009 for 25 MV photon beams.

No systematic differences were observed for the holder correction factors in open or wedged beams of the same field size. For a fixed photon beam quality all deviations between correction factors determined at different field sizes were smaller than 0.3%. The measurement data were averaged over a series of measurements with the reproducibility of 0.2% (one standard deviation) in several series.

The study allowed extracting correction factors for the new TLD holder with a horizontal arm for any clinically applied photon beam quality. The range from Co-60 to 25 MV photon beams was covered adequately.

D. The main conclusions of the meeting

The strategy for national TLD programmes has been developed involving three subsequent audit steps for beam output in reference conditions for high-energy photon beams (step 1), dose in reference and non-reference conditions on the beam axis for photon and electron beams (step 2), dose in reference and non-reference conditions off axis for open and wedged symmetric fields with an option for asymmetric fields for photon beams (step 3).

The present CRP focuses on development of the steps 2 and 3, for which procedures have been prepared that are being tested by the national EAGs and, at a later stage, will be implemented for systematic dosimetry audits of radiotherapy hospitals at the national level.

Based on the IAEA standard TLD holder for high-energy photon beams, a special TLD holder with horizontal arm was developed that enables off-axis measurements. New procedures were prepared for the TLD irradiation at hospitals with the relevant instructions and data sheets. The off-axis measurement methodology for photon beams was successfully tested in a multi-centre pilot study.

The degree of implementation of the TLD based quality assurance programmes for radiation therapy dosimetry in non-reference conditions in participating countries differs in various countries. All EAGs performed feasibility studies for the step 2 for photon beams and the pilot studies with a selected group of hospitals are in progress. Two participants are ahead of the group with their work, two progress with acceptable speed and for three others, the project implementation rate is somewhat slower.

The detailed work plans for all project participants in 2005-2006 were outlined.

E. Recommendations to participants

- All participants will continue TLD audit step 1 for new installations that have not participated in the TLD audit before.
- Bulgaria, Cuba and India will complete/repeat the feasibility studies in non-reference conditions on-axis (step 2) to reach the adequate compatibility with the implementation level of other participants.
- All EAGs, except for Argentina and Poland, who have already done the relevant work, will conduct pilot TLD runs for the audit step 2 for photon beams with a few local hospitals. Algeria, China and India will conduct or repeat TLD pilot runs for electron beams.
- All EAGs will adapt procedures for the audit step 3 (off axis, symmetric fields, photon beams) to the local

conditions and will prepare the relevant TLD instructions and data forms in national languages. Feasibility studies to test the procedures will follow.

- Once the EAG feasibility studies of the step 3 have been successful, TLD pilot runs with the selected group of hospitals will follow in each participating country. These checks will be done only in those hospitals for which the results obtained in the previous audit steps are fully acceptable.

F. Recommendations to the IAEA

- The IAEA, in conjunction with AKH and ESTRO will develop procedures and TLD forms for the audit step 3 for photon beams, asymmetric fields. The IAEA will make available to EAGs appropriate documentation and forms for measurements at national levels.
- The IAEA will develop TLD evaluation spreadsheets for various audit steps to be adapted by national EAGs.
- The IAEA will make available to the EAGs of the participating countries all appropriate documentation, reports and minor laboratory supply, such as a modified TLD holder.
- The IAEA Dosimetry Laboratory will provide reference irradiations to the EAGs and other relevant support to ensure that EAGs' TLD systems operate at a level compatible with international standards.
- The IAEA Dosimetry Laboratory will continue the regular TLD audits for the national TLD Measuring Centres in the EAGs of the participating countries.

COURSES, MEETINGS AND CONSULTANCIES TO BE HELD DURING 2005

Courses and workshops

Workshop on Training of Audit Teams for Comprehensive Audit in Radiotherapy, Vienna, 9–11 May 2005

Regional (RAF) Training Course on physical aspects of SPECT imaging, Cairo, Egypt, June 2005 (date and location to be confirmed during first Coordination Meeting)

Regional Training Course on Quality Assurance of Physical and Technical Aspects in Radiotherapy, Argonne National Laboratory, Illinois (USA), 6–17 June 2005

Regional Training and Educational Workshop on Physical Aspects of Quality Assurance in Radiotherapy, Asia and Pacific Region (place not yet known), August 2005

Regional Training Course on Monitor Unit Calculations, Tunis, Tunisia, September 2005

Meetings and consultancies

First Coordination Meeting for AFRA Regional Project RAF/6/032: Promoting Regional and National Quality Assurance Programmes for Medical Physics in Nuclear Medicine, Cape Town, South Africa, January 2005

Consultant's meeting on QA of dosimetry calculation in external radiotherapy, Vienna, March 2005

Consultants Meeting on Acceptance Testing of Treatment Planning Systems (TPSs) for CRP E2.401.13, IAEA, Vienna, 14–18 March 2005

Research Coordination Meeting on the CRP E.2.40.14 "Development of procedures for in vivo dosimetry", IAEA, Vienna, 4–8 April 2005

Consultants Meeting on Updating the Code of Practice for Dosimetry in X-Ray Diagnostic Radiology, IAEA, Vienna, 11–15 July 2005

Consultants Meeting on Preparation of Education Materials on Medical Physics based on the IAEA Syllabus, IAEA, Vienna, 8–12 August 2005

Consultants Meeting to review and edit the draft document "Guidance to SSDLs on the assessment of measurements uncertainty for Secondary Standards Dosimetry Laboratories", IAEA, Vienna, 19–23 September 2004

Consultants Meeting to review and edit the draft document on the training programme in calibration and quality control procedures, IAEA, Vienna, 7–11 November 2005

First Coordination Meeting for AFRA Regional Project RAF/6/031: Medical Physics in Support of Cancer Management, Cape Town, South Africa, 21–25 November 2005

Research Coordination Meeting on Testing Implementation of the Code of Practice on Dosimetry in X-Rays Diagnostic Radiology, IAEA, Vienna, 28 November–2 December 2005

Consultants Meeting on Quality Control in Mammography, IAEA, Vienna, 5–9 December 2005

Consultants Meeting on Preparation of the Syllabus for the "Handbook of Diagnostic Radiology Physics", IAEA, Vienna, 12–16 December 2005

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Laboratory of Ionizing Radiation, Slovak Institute of Metrology (SIM)	Bratislava, SLOVAK REPUBLIC
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)	Madrid, SPAIN
National Physical Laboratory (NPL)	Teddington, UNITED KINGDOM
National Institute of Standards and Technology (NIST)	Gaithersburg, USA

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