IAEA/WHO
NETWORK OF
SECONDARY
STANDARD
DOSIMETRY
LABORATORIES

SSDL NEWSLETTER

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of the SSDL Network

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CONTENTS

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EDITORIAL NOTE

A standing Scientific Committee of the IAEA/WHO Network of Secondary Standard Dosimetry Laboratories (SSDLs) was established in 1986 by the General Directors of the IAEA and the WHO to review and evaluate the work of the IAEA/WHO SSDL Network. The purpose of the SSDL Scientific Committee is also to evaluate the work of the Dosimetry and Medical Radiation Physics Section (DMRP) and advise the Director General on the strategies of the Dosimetry programme of the Agency that will meet the needs of the Member States. The Scientific Committee meets regularly every two years for this purpose.

Certain tasks of the DMRP Section are supported by external Consultants, specialists in certain topics where either staff of the Section has not enough expertise or enough time to dedicate, who contribute to the establishment of new techniques, calibration procedures, dosimetry recommendations, etc. Their work is normally carried out in Consultant Meetings at the Agency headquarters in Vienna.

In addition to providing services to Member States (the SSDL network, postal dosimetry, intercomparisons, etc) and technical support to IAEA Technical Cooperation projects, the DMRP Section conducts a few Coordinated Research Programmes (CRPs), where group of scientists from industrialized and developing countries work together to investigate new fields in dosimetry, establish new procedures, etc. The group meets in so-called Research Coordination Meetings, RCM.

This issue of the SSDL Newsletter consists of three reports, one from each of these types of meetings. The first is the report of the 7th Scientific Committee meeting held during 30 September - 4 October 1996. The next one is the report from a Consultants meeting held in November 1996 and finally there is a report from a RCM held in December 1996. All these reports are published here in order to inform Members of the Network on current trends and possible changes of dosimetric practices as well as recommendations to the Agency which might affect the future work in the Member SSDLs. For this reason, the editorial board has decided to publish such reports in the SSDL Newsletter.

The editor wishes to draw the readers attention specifically to the recommendations of the Scientific Committee. The implementation of recommendation No. 2 to exclude “inactive SSDLs” from the Network was slightly modified to enable inactive laboratories to reassure their interest in the participation in the Network activities. Therefore, it was decided to use two separate lists of Members laboratories in the Network; those which are considered “active” and those who did not respond to any communications from the Network Secretariat (“inactive” SSDLs). Laboratories in the latter category might - if the lack of response continues - be excluded from the member list in the future. Note that an SSDL might well have had some time period without any activities and still be considered “active”; - this is subject to the condition that the SSDL continues submitting the Annual Report and maintaining contacts with the Network Secretariat.

The SSDL Scientific Committee also recommended the Agency to develop an SSDL Charter detailing the responsibilities and tasks of the SSDLs in the Network. As a consequence of that recommendation, a Consultants meeting on this task was organized and held in May 1997. The result of this meeting will be published in a special issue of the SSDL Newsletter.

The second article is the report from a Consultants Meeting related to the development of an international Code of Practice for dosimetry calibrations in terms of absorbed dose to water, $N_{D,w}$. As mentioned in an earlier issue of the SSDL Newsletter, it is not recommended to give hospitals calibration factors in $N_{D,w}$ until such a Code of Practice is established. The reader will, from the second article, notice that there is still a lot of work to be done before calibrations in terms of dose to water can be disseminated to Hospitals. The time estimate is about 5 years until the new Code of Practice will be finalized. It was assumed that the current discrepancies between Primary Standard laboratories will also be minimized or solved within that time frame. The latter is needed for worldwide harmonization of the dosimetry in terms of absorbed dose to water.

The last article is a report from a Research Coordination Meeting held in December 1996. The Coordinated Research Programme related to that meeting is on the use of plane parallel plate ionization chambers in therapeutic electron beams, having a verification of the recent TRS-381, the IAEA Code of Practice for plane parallel ionization chambers.

CONTRIBUTIONS FROM MEMBER LABORATORIES TO THE SSDL NEWSLETTER

The editor has received one contribution from the SSDL in India - an article describing their TLD dose check services to hospitals. We also received a booklet from one SSDL in Europe describing their facilities. The former will soon be published in the SSDL Newsletter. The latter needs more editing and selecting of a part of common interest before publishing. It is a promising trend that Member laboratories start to submit contributions and we are open to accept more contributions.

Georg Matscheko and Pedro Andreo.

As of July 1997, The staff at the Dosimetry and Medical Radiation Pysics Section is

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There is a general e-mail address of the DMRP Section where all correspondence not related to specific tasks of the staff above should be addressed. Please note also that there is a considerable circulation of staff of the Agency, so that messages addressed to someone who has left might be lost. The mailbox is DOSIMETRY @IAEA.ORG, and all incoming messages to this mailbox are internally distributed to relevant staff members.

ACCREDITATION OF A NETWORK MEMBER LABORATORY

The SSDL in Cuba is, to our knowledge, the first SSDL that has been accredited according to ISO 9000 by a national accreditation body. This SSDL was nominated for the Network Membership in 1995 - only two years ago. The Network Secretariat wishes to compliment the SSDL in Cuba for its success.

The accomplishment of the Cuban SSDL is worth celebrating. But - without intending to discourage any SSDL to aim for its accreditation, nor to try to lessen the success reached by the Cuban SSDL - it might be worth commenting that the Network Secretariat does not feel that accreditation is a major goal for its Member Laboratories. This is due to the costs normally involved in the accreditation procedure and the fact that the SSDLs probably are the most competent bodies in radiation dosimetry within their countries (at least if the country has no PSDL). Nevertheless, in some countries accreditation might be crucial for reaching recognition by all those who might need the services of the SSDL. Thus, depending on national/regional background, the need for accreditation may vary strongly and each Member Laboratory must decide whether or not it is worth aiming for.

REPORT OF THE SEVENTH MEETING OF THE SSDL SCIENTIFIC COMMITTEE (SSC)

Vienna, 30 September - 4 October 1996

1. FOREWORD

The report on the sixth meeting (held in March 1995) of the Scientific Committee of the IAEA/WHO Network of Secondary Standard Dosimetry Laboratories (SSC) was published in the SSDL Newsletter No 33, July 1995.

The seventh meeting was held in Vienna at the Agency headquarters on 30 September to 4 October 1996. Opening remarks by Mr. S. Machi, Deputy Director General, Department of Research and Isotopes (RI), Mr. P. R. Danesi, Director of the Agency's Laboratories (RIAL), and Mr. P. Andreo, Head of the Dosimetry Section, speaking for Mr. A. Cuarón, Director of the Division of Human Health (RIHU), reviewed the mission and functions of the Agency, the Agency's Laboratories, and the Dosimetry Section. For the first two days the Agency staff members presented reports on their various activities. On Wednesday morning the SSC toured the Agency's Dosimetry Laboratory facilities at Seibersdorf. The SSC then met in closed session with Mr. P. Andreo until Friday noon, deliberating its recommendations. The list of participants in the meeting and the meeting agenda are enclosed as Appendix I and Appendix II, respectively.

According to the Terms of Reference, the SSC evaluated the activities of the Dosimetry Section reported for 1995-1996 and discussed the proposed programme for the Section for 1997-1998. Long-term plans for seminars and teaching courses (until the year 2000) were also discussed. The scope of the evaluation was addressed to the fundamental questions of:

- the objective of the programme area,
- the impact (benefits to the Member States),
- its continuing relevance as an Agency activity.

Specific advice or recommendations from the SSC are underlined in the text, and reiterated at the end of the report.

The Committee wishes to commend the Agency Staff for their clear and comprehensive presentation of the various programmes and their forthright and expert responses to all questions from the SSC. The Committee particularly wishes to commend the Dosimetry Section Head for providing, in advance, a concise written overview of the activities of the Section, so that new SSC members had a clear idea of the overall picture prior to the meeting.

Following the recommendation of the last SSC, the Committee has been expanded to add one member with expertize in dosimetry at the high-dose levels used in radiation processing. This has added a needed competence to the Committee and improved our ability to evaluate and give guidance to the whole programme as well as radiation processing.

2. INTRODUCTION

The Committee is pleased to note that since the last meeting of the SSC, the staff of the Dosimetry Section have made effective response to all recommendations of the previous SSC (March 1995). In general all activities of the Dosimetry Section support the aims of the Agency's Dosimetry Programme.

The Dosimetry Section's activities have been reorganized slightly so that they are now performed under four Projects:

- PROJECT E.3.01: Secondary Standard Dosimetry Laboratory (SSDL) Network
- PROJECT E.3.02: Dose Intercomparison and Assurance
- PROJECT E.3.03: Transfer of Dosimetry Techniques
- PROJECT E.3.04: Technical Backstopping of TC Activities

This report begins with a general discussion of administrative items and collaborative efforts within the Agency. Each project is then discussed in turn. The Committee was presented with reports of the many facets of the Dosimetry Section's Programme in support of its stated mission. This report will summarize only those activities of the Section for which the SSC has comments or recommendations. Exclusion of specific activities should be interpreted positively, as concurrence by the SSC with the activity as reported.

3. REPORT

3.1. General Organizational Items

3.1.1. The Agency's Dosimetry Laboratory

The activities of the Agency' Dosimetry Laboratory involve sophisticated technologies requiring high precision measurements. In addition the work has world-wide impact on the standardization of dosimetry measurements, and individual reports may have profound impact on individual patients and products.

The Committee, therefore, recognizes that the programmatic, scientific, and technical supervisory responsibilities of the Agency's Dosimetry Laboratory reside with the Head of the Dosimetry Section (RIHU).

The SSC is pleased that the Agency's Dosimetry Laboratory has been organized into four areas of activity which represent four distinct technologies in dosimetry, generally requiring separate expertise and separate equipment. The four areas presently covered by the Agency's Dosimetry Laboratory are:

a) External Radiotherapy and Radiation Protection Dosimetry standardization,

b) Radiotherapy Dosimetry Quality Assurance (IAEA/WHO TLD Service),

c) Radiation Processing Dosimetry Quality Assurance (IDAS),

d) Brachytherapy Dosimetry Standardization.

Because of the differences in the techniques used in each area, these generally require supervision by separate professional staff. Therefore it is important that separate professional (P rated) staff of the Dosimetry Section be responsible for each separate area of activity. Close guidance and supervision require regular participation in the experimental work at the Agency's Dosimetry Laboratory by the respective staff members.

Because of the technical sophistication and serious responsibility of the Dosimetry Laboratory, as discussed above, the SSC recognizes the importance of the direct link which now exists between the Dosimetry Section Head (RIHU) and the Director of the Agency's Laboratories (RIAL).

3.1.2. Collaboration between various Divisions at Headquarters

The SSC applauds the participation of the Dosimetry Section in the agreement between the Agency's Divisions RIHU and NSRW described in the Inter Office Memorandum from the Division

Directors, Mr. A. J. González and Mr. A. Cuarón, addressed to the Directors of the Divisions TCPM and TCIM, Mr. P. Barretto and Mr. A. El-Saiedi, dated 7 August 1996 entitled "Assurance of Quality and Safety in the implementation of Radiotherapy Projects". The SSC believes that this collaboration will assist rational planning and improve the effectiveness of the Agency in the implementation of Technical Co-operation projects in this field.

3.2. Project E.3.01: Secondary Standard Dosimetry Laboratory (SSDL) Network

The IAEA/WHO SSDL Network presently consists of 69 SSDLs, 6 National SSDL Organizations and 19 affiliated Laboratories in 57 countries. These SSDLs provide instrument calibration for radiation therapy and radiation protection, evaluate personnel dosimeters, provide quality audits of radiotherapy dosimetry by both postal TLD and on-site measurements, occasionally provide on-site therapy unit calibration at hospitals, and perform measurements at radiation processing dose levels. The services provided vary widely depending on the SSDL.

3.2.1. TLD monitoring of SSDL measurements at therapy level

For 15 years a postal TLD programme has monitored the performance of the SSDLs in the therapy dose range. Results of this programme indicate that more than 90 % of the SSDLs that participate in this intercomparison have been within ±3.5 % of the Agency's standard.

The results for 1995 for laboratories providing therapy-level calibrations are given in Figure 1, where the deviations from the Agency standard are plotted for Cobalt-60 and high-energy x-rays.

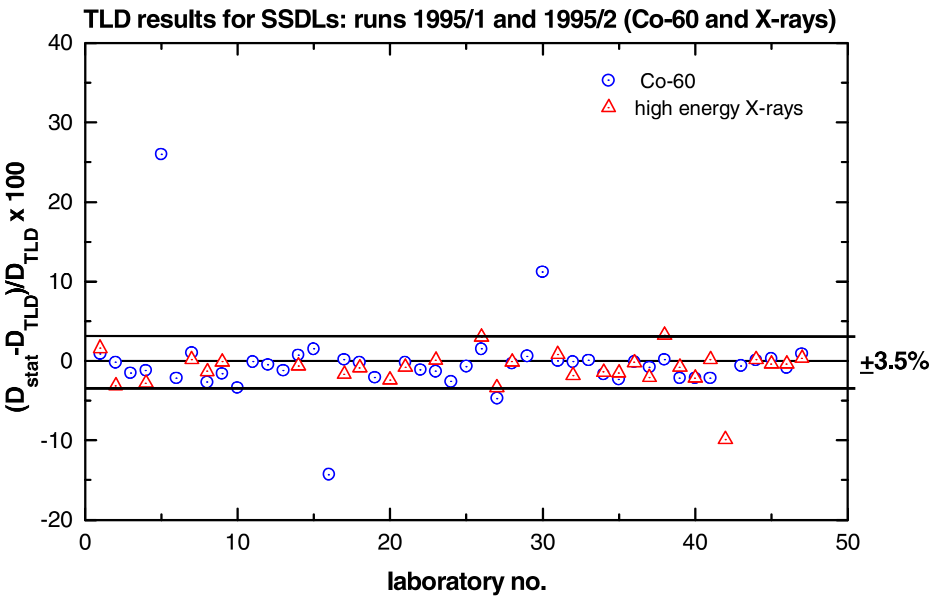

FIG. 1. Results of the IAEA/WHO TLD quality audits of SSDLs for the delivery of dose to water under reference conditions during 1995. Data shown correspond to deviations (in percent) of the dose stated by the SSDL (D_{stat}) relative to the dose determined at the Agency's Dosimetry Laboratory from the TL-signal (D_{TLD}). Each data point corresponds to the average of 3 TLDs. A total of 75 beam calibrations were checked in 47 laboratories, that include 45 Co-60 beams (circles) and 30 high-energy X-ray beams (triangles). Five deviations were found outside the acceptance limit of ±3.5 %.

The Committee is pleased that a programme to follow up on SSDLs whose TLD results are outside the ±3.5 % criteria has been established to resolve discrepancies. Those laboratories with deviations outside the limit are informed of the discrepancy and assisted by the Agency to correct the problem, thus avoiding potential propagation of errors to patients treated within the country. The SSC commends the Agency on these efforts.

3.2.2. Membership in the Network

Following the recommendations of this Committee in our 1995 report, the Agency has sent letters to all SSDLs questioning their intent to remain affiliated with the Network. There were 7 SSDLs who failed to respond even after two letters; these SSDLs have also failed in submitting annual reports for the past two years and have not participated in quality audits for two years. The SSC recommends that the Agency interprets this as a lack of interest in participating in the Network and that a letter be sent, through the Government Mission, indicating these deficiencies, and suggesting that the Agency intends to drop the SSDL from the Network unless positive action is taken.

3.2.3. Seminar and Training Course for all SSDLs

The SSC supports the proposal by the Dosimetry Section to hold an Interregional Seminar on “Quality Assurance in the IAEA/WHO Network of Secondary Standard Dosimetry Laboratories (SSDLs)” in 1999. The SSC recommends that the Seminar be designed so that all of the SSDLs be represented, as this should improve the quality of radiation dosimetry throughout the entire network. The SSC further suggests that the Agency consider presenting the Seminar in conjunction with the proposed Interregional Training Course on “Calibration Procedures and Quality Assurance in the SSDLs” in 1999. The SSC noted that in the nearly 30 years of existence of the network, no seminar or workshop of this scope has been held.

3.2.4. SSDL charter

The SSC recommends that the Agency develops an "SSDL charter" detailing the responsibilities and tasks of the SSDLs which will cover at least the following topics:

a) the tasks and duties of the SSDLs (capabilities, services, quality assurance procedures, annual report, etc.),
b) the relationship of the SSDLs with the International Measurement System,
c) the traceability of the SSDLs to Primary Standards,
d) the policy for relations between the SSDLs and users,
e) the procedure for the resolution of measurement discrepancies among the Agency, the SSDLs and their users.

This document should be ready to be presented at the Interregional Seminar and/or the Interregional Training Course planned for all SSDLs in 1999 (see Table 2 in section 3.4.2 below). The task should be combined with two CRPs already in place, “Development of a Quality Assurance programme for Secondary Standard Dosimetry Laboratories” and “Development of a Quality Assurance programme for Radiation Therapy Dosimetry in Developing Countries”.

3.2.5. Quality Assurance Manual

The Dosimetry Section is developing a comprehensive Quality Assurance Manual for the activities performed at the Agency's Dosimetry Laboratory, in a format intended to comply with ISO/IEC Guide 25 requirements. A significant fraction of the manual has been drafted. The Committee congratulates the Dosimetry Section on the speedy preparation of the manual. The SSC recognizes that the manual will not only be useful in the Agency's Dosimetry Laboratory, and recommends that it also serves as a model for the SSDLs to develop their own manuals.

3.2.6. Brachytherapy

The SSC commends the Dosimetry Section on the successful work on brachytherapy standards since calibrated Cesium-137 sources became available in spring 1996. The SSC recommends continuation of the effort to establish calibration services in brachytherapy, so that calibration of well ionization chambers can be provided to the SSDLs.

3.2.7. Radiation protection and diagnostic x-rays dosimetry

Nearly 80 % of the SSDLs provide measurements in the radiation protection range. The SSC recommends that the Agency takes every necessary effort to ensure that SSDLs measurements in radiation protection are traceable to Primary Standards. As the Agency's Dosimetry Laboratory provides traceable calibrations of ionization chambers in terms of air kerma at radiation protection levels, the SSC encourages the SSDLs to use the service available from the Agency to provide traceability for their radiation protection measurements.

Measurements on diagnostic x-ray machines have become increasingly important and some SSDLs are involved in such measurements. The Agency's Dosimetry Laboratory should, therefore, have proper radiation sources available to provide traceable calibrations to the SSDLs. As a first step the Agency's Dosimetry Laboratory has acquired a conventional diagnostic x-ray unit. Because of the importance of mammographic examinations world-wide, the Agency's Dosimetry Laboratory should also be equipped with an x-ray unit specific for mammography.

The annual postal comparison has been shown to be successful in assuring the coherence of the measurement quality of the SSDL Network in the range of therapeutic doses. This programme should be extended to assure the traceability of secondary standards also at radiation protection dose levels and diagnostic x-rays. The SSC recommends that the Agency's Dosimetry Laboratory should start the task for Radiation Protection measurements using Cesium-137 gamma radiation at protection levels; implementation of these services will require an additional technical staff member.

3.3. Project E.3.02: Dose Intercomparison and Assurance

3.3.1. The IAEA/WHO TLD postal service

The IAEA/WHO TLD postal programme for monitoring the calibration of radiotherapy beams at hospitals in Member States continues with approximately 200 hospitals measured per year. The results for all TLD measurements at hospitals for the past 3 years are shown in figure 2. Approximately 2/3 of the hospitals are within ±5 % of the Agency's standard.

There are several areas of concern in this programme that have been identified by the Agency and WHO. The SSC agrees that these are valid concerns:

a) approximately 1/3 of the results are outside the ±5 % limit,

b) there is a significant delay (up to 6 months) between irradiation of the TLDs and receipt of the IAEA's evaluation report by the hospitals through WHO,

c) 40 % of the TLDs are not returned to WHO and the Agency for evaluation.

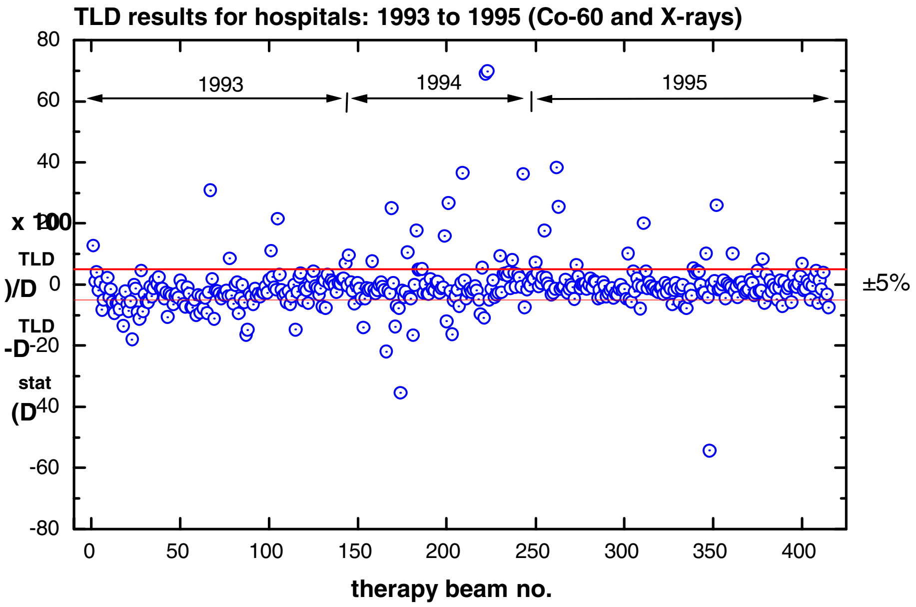

FIG. 2. Results of the IAEA/WHO TLD quality audits of radiotherapy institutions for the delivery of dose to water under reference conditions during 1993-1995. Data shown correspond to deviations (in percent) of the dose stated by the hospital (D_{stat}) relative to the dose determined at the Agency's Dosimetry Laboratory from the TL-signal (D_{TLD}). Each data point corresponds to the average of 3 TLDs. The number of therapy beam calibrations checked during these years were 144 in 1993, 97 in 1994 and 174 in 1995, with 32 %, 29 % and 16 % of the respective deviations outside the acceptance limit of ±5 %.

The major positive aspect of the programme is the efforts undertaken by the Agency and WHO to follow up on those results outside the limits. The programme presently followed for those institutions outside the ±5 % limits is:

a) Inform the hospital that they are outside the ±5 % limit without indicating the extent of the disagreement (blinded),

b) Request the hospital to irradiate another TLD set,

c) If the second TLD is outside the limits, the appropriate SSDL is asked to help resolve the discrepancy and, if needed, an expert mission may be authorized for on-site measurements to resolve the discrepancy.

The SSC commends the Dosimetry Section on this procedure.

The Agency presently performs the TLD service in a "batch" process in which a large number of hospitals (approximately 60) are sent TLD through WHO and asked to irradiate the TLDs within a fairly narrow time window; the evaluation is not performed until all TLDs are returned. The SSC agrees that this may be a significant contributor to the lengthy turnaround time for the reports. The Agency is discussing a "modified batch" or even "continuous" process whereby the irradiation windows may be significantly relaxed or eliminated, and the evaluation will be done as TLDs are returned to the Agency. The SSC believes that these new procedures may significantly reduce the turnaround time and may even reduce the number of non-returned TLDs. The SSC therefore recommends that the Agency continue to evaluate the new procedures and implement them as soon as possible.

The Agency also is considering purchasing a new automatic TLD reader which could evaluate a large number of TLDs more rapidly, and include semi-automatic evaluation of the results. The SSC recommends that the Agency evaluates the new reader equipment, purchase the appropriate unit(s), and implement the automated system as soon as possible. The main objective should be a substantial increase in the number of hospitals monitored.

3.3.2. Transfer of TLD programme to SSDLs

The Agency has performed pilot studies at two SSDLs which had experience with postal TLD. The objective of these pilot studies was to:

a) Increase the technical capacity of National Centers (SSDL),

b) Free the Agency to provide services elsewhere,

c) Provide services from National Centers comparable to, or better than, the Agency's; by providing results more rapidly and providing local follow-up for hospitals whose TLD results were outside the limits.

The Agency provided the TLD and evaluated the results while monitoring the study; the SSDL distributed the TLD and used their own TLD system to read the dosimeters. These pilot tests were also intended to evaluate whether the SSDL could perform the programme successfully in their own country before transporting the service to other countries in the region.

The SSC recommends that the transfer of responsibility to the SSDLs continue to be a priority for the Agency. The findings from these pilot studies did not completely satisfy the expectations, so additional work and additional studies are needed. These can be developed under the present CRP on "Development of a quality assurance programme for radiation therapy dosimetry in developing countries".

3.3.3. Collaboration between the Agency and the WHO

The SSC is pleased with the long standing collaboration between the Agency and the WHO. The committee hopes that the collaboration continues and, in fact, increases as the need for the service increases in developing countries. The SSC emphasizes that the impact of this programme on individual hospitals and patients can be significant. We see in Figure 2 that the majority of institutions are within the ±5 % limits, but 1/3 continue to be outside. Efforts to bring these hospitals within the limits will require continued interaction between the Agency and the WHO. It would be profitable if the WHO would initiate some clinical studies in parallel with the TLD service to evaluate the impact on patient treatment.

The SSC is concerned that at the present time no professional staff is available in the WHO Headquarters Radiation Medicine Unit. This will not allow the WHO to maintain collaboration with the Agency at an adequate level and will have a negative impact on the effectiveness of the IAEA/WHO TLD service and thus on radiation therapy in developing countries.

3.3.4. Radiation Processing Dosimetry

The Agency continues to provide the International Dose Assurance Service (IDAS) at radiation processing dose levels using alanine dosimeters issued and measured by the Agency's Dosimetry Laboratory. An audited traceability chain has been established to a Primary Standards Laboratory. The SSC thanks the Director General for agreeing to waive the requirements for a fee for this service and for allowing direct contact between the Dosimetry Section and users in Member States. This action has resulted in a significant increase in participation in the programme and the SSC recommends that the practice continues.

During 1995, 54 dose assurance checks were carried out of which 70% showed agreement within the action limit of ±5 %. The Agency is placing increasing emphasis on resolving discrepancies of greater than the ±5 % action limit, and has recently introduced a system of "blind" repeat checks to assist this process. The SSC commends the Agency on this initiative. The SSC was pleased to note the success of a major intercomparison at radiation processing dose levels that was undertaken by the Agency in collaboration with BIPM. The intercomparison involved nine calibration laboratories, including five Primary Standard Laboratories. The results showed dose estimates from the participating laboratories to lie within a population of standard deviation 2.1 % at 15 kGy and 2.4 % at 45 kGy.

3.4. Project E.3.03: Transfer of Dosimetry Techniques

The transfer of dosimetry techniques in the Agency's Dosimetry Programme is provided through coordinated research programmes (CRPs), training courses, fellowships, seminars, symposia, and publications. Technical Co-operation projects (TCs), which are an important way to transfer technology to developing member states, are covered under Project E.3.04.

3.4.1. CRPs

The list of ongoing and proposed CRPs is included in Table 1. The only CRP for which the SSC has any comment is the proposal to coordinate a "CRP on development of procedures for the determination of absorbed dose with therapeutic photons, electrons, and proton beams based on measurement standards of absorbed dose to water". Following the recommendations of the previous SSC report, the Agency has convened a Consultant Group that will meet in November 1996 to discuss this issue. The SSC recommends that the Agency investigate the effects of the new standards of absorbed dose to water on current procedures at the SSDLs and hospitals and produce a new protocol based on absorbed dose standards, when the time is appropriate.

TABLE 1. COMPILATION OF COORDINATED RESEARCH PROJECTS (CRP)

Year of start	**Subject**	**Year of Completion**	**Participating Institutions**
1988	Development of quality control dosimetry techniques for particle beam radiation processing	1995	9
1995	Characterization and evaluation of high dose dosimetry techniques for Quality Assurance in radiation processing	1999	9
1995	Development of a Quality Assurance programme for Secondary Standard Dosimetry Laboratories	1998	7
1995	Development of a Quality Assurance programme for Radiation Therapy Dosimetry in Developing Countries	1998	9
1996	Code of practice for radiation measurement with plane parallel ionization chambers	1999	7
1997 to be proposed	Development of procedures for the determination of absorbed dose with therapeutic photon, electron and proton beams based on measurement standards of absorbed dose to water	2001	

3.4.2. Training Courses and Symposia

The proposed schedule of Training Courses and Symposia for the period 1996 - 2000 is listed in Table 2.

Although the SSDL programme has been in existence for nearly 30 years, a programme to educate and train all SSDLs on modern techniques has never been held. The proposed Interregional Seminar and Interregional Training Course, discussed in Section 3.2.3 above, and scheduled for 1999, are such meetings. It is hoped that all of the SSDLs would participate in at least one of these programmes. The training course should be designed for SSDL staff members who actually perform the measurements.

3.5. Project E.3.04: Technical Co-operation

The SSC is very pleased that there has been a major trend to increased support from the Technical Cooperation Programme for Quality Assurance Programmes in Radiotherapy Physics and for the training of Medical Physicists.

TABLE 2. PROPOSED SCHEDULE OF TRAINING COURSES, SEMINARS AND SYMPOSIA
Approved programmes are indicated by underlining the dates.

TRAINING COURSES PLANNED FOR THE PERIOD 1996-2000 (GOV/INF/774, 31 Oct 95)		
1996	Regional Course Quality Assurance in Radiotherapy Dosimetry	EAST ASIA AND PACIFIC Manila, Philippines
1997	Regional Course Treatment Planning Techniques and Dosimetry in Radiotherapy	AFRICA
1998	Regional Course Quality Assurance in Radiotherapy Dosimetry	AFRICA
1998	Regional Course Treatment Planning Techniques and Dosimetry in Radiotherapy	LATIN AMERICA
1998	Regional Course Quality Assurance and Dosimetry in Radiotherapy	MIDDLE EAST - EUROPE
1999	Regional Course Modern Techniques and Dosimetry in Brachytherapy	AFRICA
1999	Regional Course Modern Techniques and Dosimetry in Brachytherapy	EAST ASIA AND PACIFIC
1999	Interregional Training Course Calibration procedures and Quality Assurance in SSDLs	Vienna
PROPOSED MAJOR MEETINGS FOR THE PERIOD 1996-2000		
1998	Symposium Dosimetry for Radiation Processing and Therapy	Vienna
1999	Interregional Seminar Quality Assurance in the IAEA/WHO network of SSDLs	

4. RECOMMENDATIONS

Specific recommendations are underlined in the text. Each is summarized below with reference to the specific section of the Report. The SSC recommends that:

1 The programmatic, scientific, and technical supervisory responsibilities of the Agency's Dosimetry Laboratory reside with the Head of the Dosimetry Section (RIHU). Separate professional (P rated) staff of the Dosimetry Section should assume direct responsibilities for separate areas of activity (see Section 3.1.1).

2 Letters be sent, through the Government Missions, to all SSDLs considered to be inactive, informing them of the Agency's intent to drop them from the IAEA/WHO SSDL Network (see Section 3.2.2).

3 The Seminar and Training Course for SSDLs, proposed by the Dosimetry Section for 1999, be designed and organized so that all SSDLs be represented (see Section 3.2.3). The training course should be designed for the SSDL staff members who actually perform the measurements. (see Section 3.4.2).

4 The Agency develop an "SSDL Charter" detailing the responsibilities and tasks of the SSDLs

(Section 3.2.4). This should be ready for presentation at the proposed 1999 Seminar/Training Course.

5 The Agency's Dosimetry Laboratory Quality Assurance Manual be made available as a model for the SSDLs (see Section 3.2.5).

6 The Agency continue efforts to provide calibration services for brachytherapy to the SSDLs (see Section 3.2.6).

7 The Agency take every effort to insure that the SSDLs measurements in radiation protection are traceable to Primary Standards (see Section 3.2.7).

8 The Agency's Dosimetry Laboratory be equipped with appropriate radiation sources for dosimetry standardization in diagnostic x-rays, including mammography (see Section 3.2.7).

9 The traceability of secondary standards in SSDLs for radiation protection be assured with postal TLD measurements; this activity should start with measurements using Cs-137 gamma rays (see Section 3.2.7).

10 The Agency and the WHO Radiation Medicine Unit, in collaboration with the Regional Offices, continue efforts to improve the turnaround time for the TLD system used for dose quality audits in radiotherapy beams (see Section 3.3.1).

11 The transfer of responsibility for dose quality audits of hospitals, using TLD, continues to be a priority for the Agency (see Section 3.3.2).

12 The practice of waiving the fee to participate in the IDAS, and for allowing direct contact between the Dosimetry Section and users in Member States, be continued as this has resulted in a significant increase in participation in the programme (see Section 3.3.4).

13 The Agency investigate the effects of the new standards of absorbed dose to water on SSDLs and hospitals, and produce a new Code of Practice based on absorbed dose standards when the time is right (see Section 3.4.1).

5. CONCLUDING COMMENTS

The SSC again commends the Staff of the Dosimetry Section for their comprehensive presentation of the Agency's Dosimetry programme. The Agency's Dosimetry projects are vital to ensure the quality of radiation dosimetry at various dose levels in developing countries.

The present programme brings radiation standards available to the majority of developing countries. External beam radiation therapy and radiation processing (high dose) have the most robust link to international standards. The Agency is working to establish links for brachytherapy and diagnostic radiology, and to strengthen links for radiation protection. Over the past several years the Agency has developed several procedures to follow up and correct discrepancies in dosimetry identified by their various postal dosimetry services. The SSC considers this a high priority item and the Agency is actively working to expand the program. The Agency in collaboration with WHO Radiation Medicine Unit, Regional Offices and national institutions continue to investigate mechanisms to transfer responsibility for postal monitoring of dosimetry to regional and national centres. The SSC commends the Agency for their efforts, but emphasizes that the transfer should only be made when it is clear that it will not jeopardize the quality of radiation dosimetry in the Member States.

The SSC commends the Agency for their continued support for the programmes sponsored through the Dosimetry Section. The Dosimetry Section continues to provide competent and professional services through these various programmes.

ABBREVIATIONS

BEV	Bundesamt für Eich- und Vermessungwesen (Austria)
BIPM	Bureau International des Poids et Mesures
CRP	Co-ordinated Research Programme
IAEA	International Atomic Energy Agency
ICRU	International Commission on Radiation Units and Measurements
IDAS	International Dose Assurance Service
NIST	National Institute of Standards and Technology (USA)
NPL	National Physical Laboratory (UK)
NSRW	Division of Radiation and Waste Safety, Department of Nuclear Safety
PTB	Physikalisch-Technische Bundesanstalt (Germany)
RI	Department of Research and Isotopes, IAEA
RIAL	Agency's Laboratories, Vienna and Seibersdorf, Department of Research and Isotopes
RIHU	Division of Human Health, Department of Research and Isotopes
RPC	Radiological Physics Center, Houston (USA)
SSC	SSDL Scientific Committee
SSDL	Secondary Standard Dosimetry Laboratory
TC	Department of Technical Co-operation. General abbreviation for Technical Co-operation project.
TCIM	Division of Technical Co-operation Implementation
TCPM	Division of Technical Co-operation Programmes
TLD	Thermoluminescent Dosimeter
WHO	World Health Organization

APPENDIX I. LIST OF PARTICIPANTS

Committee members:

Prof. A. Allisy, ICRU, Chairman of the SSC

Dr. M. Boutillon, BIPM

Prof. A. Dutreix, Belgium (not attended)

Prof. K. Hohlfeld, PTB, Germany

Dr. S. M. Seltzer, NIST, USA

Dr. P. Sharpe, NPL, UK

Dr. S. Shen, China

WHO:

Dr. V. Volodin, Co-Secretary of the SSDL Network

Observers:

Dr. W. F. Hanson, RPC, USA

Dr. A. Leitner, BEV, Austria

Dr. J. W. Müller, BIPM

IAEA staff members:

Prof. P. Andreo, Head Dosimetry Section, RIHU, Co-Secretary of the SSDL Network

Mr. P. Bera, Dosimetry Laboratory, RIAL

Mr. L. Czap, Dosimetry Section, RIHU

Mr. R. Girzikowsky, Dosimetry Section, RIHU

Dr. M. Gustafsson, Radiation Safety Section, NSRW

Dr. J. Izewska, Dosimetry Section, RIHU

Dr. G. Matscheko, Dosimetry Section, RIHU

Dr. K. Mehta, Dosimetry Section, RIHU

Dr. P. Ortiz-Lopez, Radiation Safety Section, NSRW

Dr. A. Shanta, Dosimetry Section, RIHU

APPENDIX II. AGENDA OF THE MEETING

- Opening address by DDG-RI, DIR-RIAL
- Introduction of the new Committee and remarks
  P Andreo and V Volodin (WHO), co-secretaries of the IAEA/WHO SSDL Network
- Adoption of the Agenda and nomination of rapporteur

1	Overview of the IAEA Dosimetry Subprogramme (E.3)	P. Andreo
2	Working procedures at the Agency's Dosimetry Laboratory	P. Andreo
	Quality Assurance activities in the Dosimetry Laboratory	K. Mehta
3	Project E3.01: SSDL Network	P. Andreo
	Statistical information on the Network	G. Matscheko
	Summary of activities at the various SSDL laboratories	G. Matscheko
	Work at the Dosimetry Laboratory for SSDL intercomparisons	L. Czap
	Research activities in the field of ionization chamber dosimetry	L. Czap
	Activities on the calibration of brachytherapy sources and equipment	A. Shanta
4	Project E3.02: Dose Intercomparison and Assurance	P. Andreo
	The IAEA/WHO TLD postal service:	J. Izewska
	Operation of the TLD postal service	P. Bera
	Analysis of the results produced in the TLD postal service for SSDLs and hospitals	J. Izewska
	The IDAS programme for industrial facilities:	K. Mehta
	Operation of the high-dose (IDAS) postal service	R. Girzikowsky
	Results of the high-dose (IDAS) postal service	K. Mehta
5	Project E3.03: Transfer of dosimetry techniques	P. Andreo
	Coordinated Research Projects	P. Andreo K. Mehta G. Matscheko
	Training courses and seminars	P. Andreo
	Publications	P. Andreo
6	Project E3.04: Technical Co-operation Activities (1997-98)	P. Andreo
7	Collaborations with other Divisions	P. Andreo
	Radiation protection activities with NSRW	M. Gustafsson
	Quality Assurance and Safety in Radiation Therapy: The role of the Basic Safety Standards	P. Ortiz-Lopez
8	***Visit to the Agency's Dosimetry Laboratory (Seibersdorf)***	
9	Meeting of the Committee. Draft report.	

PRESENT STATUS OF CALIBRATION OF IONIZATION CHAMBERS IN TERMS OF *ABSORBED DOSE TO WATER*; RECOMMENDATIONS FOR A NEW IAEA CODE OF PRACTICE FOR DOSE DETERMINATION IN THERAPEUTIC BEAMS TO REPLACE TRS277.

25-28 November 1996, IAEA Dosimetry Section, Vienna

The Consultants were
Dr. David Burns (DB) [BIPM]
Professor Klaus Hohlfeld (KH) [PTB, Germany]
Dr. M. Saiful Huq (SH) [USA]
Dr. Tatsuaki Kanai (TK) [HIMAC, Japan])
Dr. Fedele Laitano (FL) [ENEA, Italy]
Dr. Alan Nahum (AN) [UK]
Dr. Vere Smyth (VS) [NZ]

Participants from IAEA were:
P Andreo (PA) [scientific secretary]
L Czap (LC)
G Matscheko (GM)
K Zsdansky

SUMMARY

The present status of development of standards of absorbed dose in primary standards laboratories was reviewed. More than half of all primary standard dosimetry laboratories are developing or already have operational standards of absorbed dose to water. In both Germany and the UK absorbed dose calibrations for high energy photon beams are used as the basis of radiotherapy dosimetry, and national Codes of Practice (CoP) have been written. In the USA, an absorbed dose CoP is currently in preparation.

The Consultants' Group believed that even though the current spread among primary absorbed dose standards is greater than in air kerma standards, their use as the basis of external beam radiotherapy dosimetry will improve accuracy because the current air kerma-based CoP (TRS-277) uses theoretical methods for deriving absorbed dose that do not take into account individual variations within a particular chamber type. The data presented at this CT indicated that this variation could be greater than 1%. Direct calibration in terms of absorbed dose will potentially remove much of this variation.

The energy dependence of ionization chambers can be based on experimental data rather than theory. There will be the capability of using measured data for individual chambers. The formalism of the absorbed dose-based CoP is much simpler and likely to lead to fewer mistakes in application. Air kerma standards are all based on the same physical methods and therefore may contain unknown common errors. Absorbed dose standards are based on calorimetry, ionometry, or chemical dosimetry, and are therefore more robust.

Problems created by absorbed dose calibration factors being provided in the absence of any CoP were pointed out. The inclusion of most types of radiation used for radiotherapy under the same formalism would lead to greater dosimetric consistency.

The practical details of changing from the present air kerma-based CoP to an absorbed dose-based CoP should not cause any significant difficulty to the end users.

THE CONSULTANTS' GROUP MADE THE FOLLOWING RECOMMENDATIONS:

1. The IAEA should commission research into and the development of a new CoP for external

beam radiotherapy dosimetry based on standards of absorbed dose to water.

2. As well as the usual photon and electron beams used in external beam dosimetry, the CoP should provide a basis for the dosimetry of beams of protons and heavy ions. Due to of a lack of information, no recommendation is made on the inclusion of neutrons.

3. The new CoP should cover absorbed dose based dosimetry only. Dosimetry based on air kerma standards should follow the existing TRS 277. No recommendation was made on the transition from one to the other except that in any one country only one should be used.

4. As far as possible the new CoP should follow TRS 277 and TRS 381 in the use of terminology and symbols.

5. The CoP should follow the OUTLINE OF CONTENTS AND STRUCTURE given by the Consultants' Group.

BACKGROUND

In 1985 a group of 9 experts met at the IAEA to start writing what was to become TRS277. The final report was written by only four people, Pedro Andreo, Jack Cunningham, Klaus Hohlfeld and Hans Svensson, and the work proceeded smoothly and efficiently, being ready within two years, and was published in 1987. TRS277 set a precedent for the IAEA to issue *International Codes of Practice* (CoPs) for the dosimetry of radiotherapy beams. It was based on the calibration of ionization chambers through the so-called N_K factor, which pertains to the air kerma at a point in space in a Cobalt-60 beam. Dosimetry in (external-beam) radiotherapy based on N_K calibrations has been the norm throughout the world for the past 15 years or so, and for many years previous to that the norm was the N_X calibration factor, which is conceptually the same as N_K. The IAEA is about to publish a new CoP specifically for plane-parallel ion chambers (TRS381), which also updates certain aspects of TRS277; its role as an issuer of **International** CoPs is now well established in the radiotherapy community worldwide.

During the past 15 years or so, the ionizing radiation sections of various National Primary Standards Laboratories (PSDLs) and of BIPM have been conducting research into the development of radiation standards based on the quantity **absorbed dose to water**, as an eventual replacement for N_K calibrations. Already the dosimetry of high-energy photon radiotherapy beams is based on these absorbed dose to water standards (denoted here by $N_{D,w}$) in certain countries, principally Germany and the UK, and several other PSDLs are about to launch such services. Furthermore, today many of the Secondary Standard Dosimetry Laboratories (SSDLs) are using and in some cases even distributing $N_{D,w}$ factors and yet no well-defined procedure (i.e. protocol or CoP) on how the SSDLs should do this has been issued by the IAEA. Professor Andreo stressed that the current situation is very unsatisfactory, and that he has recently issued specific instructions (SSDL newsletter, December 1995) to the SSDLs to stop any further dissemination of these $N_{D,w}$ factors to radiotherapy clinics **until a Code of Practice has been issued, either by the IAEA or a national body, in languages that are widely understood, such as spanish or english**.

PRELIMINARY DISCUSSIONS

The purpose of the present consultants' meeting was, quoting from the official invitation letter,

to advise the Agency on the present status of calibration of ionization chambers in terms of "absorbed dose to water" and to provide recommendations for preparing a new IAEA Code of Practice for dose determination in therapeutic beams which will replace TRS277."

Should the group recommend that the IAEA should produce an $N_{D,w}$ -based CoP then the specific goal of this meeting will be to write a detailed outline of its *Contents*. Professor Andreo stressed that we should consider whether the new CoP should cover not just conventional high-energy photon and electron beams but also beams of kilovoltage x rays, protons and *so-called* heavy ions, all of which are in use today in radiotherapy. PA stressed that there was a need for a common framework for the dosimetry of all types of radiations used in external-beam radiotherapy. However, it was agreed that any new CoP should beware of giving details of procedures for particular radiation qualities where the data and the science was not sufficiently mature, as has occasionally been the case in the past. Thus, for modalities such as heavy ions it was suggested that only the general framework be given as the details would be beyond the scope and probably even the ability of the yet to be appointed task group.

A further point stressed by PA was that the new edition of TRS277 (currently in press) would, at long last, include the important changes recommended by a group of consultants in 1992 which were published in SSDL Newsletter #31 and then finally in TECDOC-897. This was proof of the IAEA's commitment to promoting the continued use of TRS277 for the foreseeable future. Dr. Huq said that in any event there was bound to be a lengthy overlap period in going from the procedures in TRS277 to those in any new IAEA $N_{D,w}$ -based CoP.

STATUS REPORTS FROM THE VARIOUS CONSULTANTS

The first day was largely devoted to orally delivered status reports from the invited consultants. This served mainly to exchange information on the current situation with regard to absorbed dose to water standards in the various countries. Each consultant submitted a written report and these are attached. Only the most relevant points from each consultant's presentation are given below. The order of presentation was alphabetical in terms of the country of origin of the consultants.

Klaus Hohlfeld

Professor Hohlfeld pointed out that in Germany they do not have TWO types of calibration factor i.e. $N_{D,w}$ and N_K , but only ONE i.e. $N_{D,w}$ to cover **all** the whole range of radiation qualities in radiotherapy. This has been the case since 1986, when a draft of the DIN was issued (DIN8600+2). This has now, in 1996, become an official DIN Standard. The only region where N_K is still employed is for diagnostic x-ray beams of 150 kV less. However, KH stressed that the air-kerma standards, i.e. the free-air chambers, at PTB have been retained.

KH stressed that the main motivation for the decisive move towards absorbed dose to water standards (ADWSs) in Germany was the desire to avoid completely the need to use factors such as k_m and k_{att} which are purely theoretical and also associated with significant uncertainties. It was **very** difficult to give uncertainties on calculated values. The uncertainties were not restricted to the physical data involved, e.g. stopping powers, mass-energy absorption coefficients; one also had to consider the (theoretical) *model* used to calculate the quantity of interest - it was virtually impossible to assign an uncertainty to this.

KH said that the SSDLs in Germany do not have linear accelerators (linacs) and would never do so. Thus these labs were restricted to Cobalt-60 gamma units and therefore the **Primary** SDL in Germany, PTB, would never issue calibration factors, i.e. k_Q , for any other reference quality than for Cobalt-60, although the PTB did have a linac. Dr. Nahum pointed out that this was in marked contrast to the policy of the UK PSDL, NPL, which issues absorbed-dose-to-water calibrations over a range of linac photon qualities (4 - 19 MV) as well as at Cobalt-60 (in terms of $N_{D,w}(Q)$ rather than $N_{D,w}$ at one reference quality together with k_Q factors as is done by PTB). Further, NPL is about to embark on a similar service for high-energy electron beams.

Fedele Laitano

Dr. Laitano stated that no $N_{D,w}$ calibrations were yet performed in Italy. In order to move to this type of calibration the Italian Dosimetry Standards Laboratory, ENEA, has developed an ADWS for Cobalt-60 based on a graphite calorimeter. However, the analysis of overall uncertainty on the final absorbed dose, D_w should be improved before moving from the Air-kerma standards (AKS) to the Cobalt-60 ADWS. In fact, at present the uncertainty on the final absorbed dose, D_w , is today not necessarily lower if based on ADWS rather than on AKS. To this end, FL stressed that experimental k_Q were urgently needed for various chambers and radiation qualities but that these measurements should be carried out at PSDLs which were equipped with linacs rather than in hospitals where the precision of the measurement setup could almost never be sufficiently high.

FL discussed the dosimetry of proton beams, which is of particular concern in Italy where a new installation for proton therapy is at the planning stage. He pointed out that there were currently three different routes and that the uncertainties were far from satisfactorily low. In FL's opinion dosimetry based on the Faraday-Cup method was totally unsatisfactory if low uncertainties were the goal. ENEA were in the process of developing an ADWS for protons, using a new design of water calorimeter with a sealed ampoule. This was currently undergoing tests in the Cobalt-60 beam. The magnitude of the *heat defect* was receiving much attention at ENEA.

Tatsuaki Kanai

Dr. Kanai outlined the dosimetry programme at HIMAC, the world's only custom-built heavy ion radiotherapy facility. He stressed that dosimetry was exceptionally complicated in this area due to the nature of the beams used (mostly Carbon ions thus far). The RBE varied strongly with depth and it was therefore necessary to explicitly arrange for the **absorbed dose** distribution in the Spread-Out Bragg Peak (SOBP) to be **non-uniform** so as to yield a **uniform** distribution of ***Biological Dose*** in Gray-Equivalent.

A particular complication in heavy-ion dosimetry is that the *W*-value varies with the particle type and in the Bragg-Peak region nuclear reactions create a whole spectrum of different particles. A further consideration is the relatively large *initial recombination* that is encountered (for example, in parallel-plate chambers) for high-LET radiation; this has been found to vary as a function of the Dose Averaged LET. Additionally there is a dependence on the gas type, with tissue-equivalent gas exhibiting the least LET dependence.

A recent comparison between three independent methods of dose determination in carbon-ion beams has yielded differences, compared to an ion chamber of -4.2% and -2.7% for the fluence measurement method (but utilising, a CR39 solid-state detector or scintillation counter instead of a Faraday Cup) and a silicon diode respectively.

Vere Smyth

Dr. Smyth emphasised that the whole of New Zealand (six RT centres) uses TRS277; so does almost all of Australia. The NZ standards laboratory, which is a **Primary** SDL, does not have the resources to develop its own ADWS; nor is VS convinced of the scientific merit of so doing. They intend to continue to use their Air-Kerma Standard.

VS stressed that clinical physicists do **not** want a lot of different options. They want a straightforward, unambiguous calibration service, preferably based on one standard ion chamber.

VS could, however, see some merit in issuing users with an $N_{D,air}$ factor, derived from a measurement *in-phantom*, rather than the current N_K factor which inevitably involved the rather uncertain factors k_m and k_{att} in the conversion to $N_{D,air}$. He remained to be convinced, however, of the advantages to the end users of making the major switch to calibrations based on absorbed dose to water standards.

Alan Nahum

Dr. Nahum outlined the progress in the UK of the NPL's absorbed dose to water calibration service. This had officially begun in 1990 with the publication of a IPSM Code of Practice in *Physics in Medicine and Biology* (Vol 35, 1355-1360). From that time onwards $N_{D,w}(Q)$ factors for the NE2561 chamber (the *secondary standard* instrument in the UK) have been supplied in the form of a calibration curve covering the photon-beam qualities from Cobalt-60 to 22 "MV" (nominal), given in terms of the *Quality Index QI*, which is identical to the specifier $TPR_{20/10}$ used in IAEA(1987) and in most other national protocols.

The NPL had been forced to increase the amount of filtration in their non-clinical linac beam in order to make it correspond more closely to a typical clinical beam; this had led to some changes (non-negligible but < 1%) in the calibration curves issued since the service started. It can be noted that the experimentally obtained change in the $N_{D,w}(Q)$ factor as a function of *QI* due to the increased (aluminium) filtration at the two lowest qualities, 4 and 6 MV, is still not fully understood on theoretical i.e. cavity-theory grounds.

One clear empirical finding from the NPL experience with the ADWS is that the behaviour of the 2561 chamber as a function of photon beam quality is extremely predictable i.e. variations from chamber to chamber are entirely negligible. It is thus unnecessary to calibrate a given user's 2561 chamber in more than one or two different qualities as the *shape* of the $N_{D,w}(Q)$ vs *QI* curve is constant. Therefore, the NPL have recently gone over to such a *quasi* k_Q approach, though it is stressed that the calibration continues to be issued as a curve of $N_{D,w}(Q)$ vs *QI* i.e. k_Q factors are not required by the user, who obtains the dose in a beam of quality *Q* simply according to

$$D_w = M_{T,P}(Q)\, N_{D,w}(Q)$$

AN pointed out that the hospital physics community in the UK would continue to use an **air-kerma based** calibration factor for electron-beam dosimetry for at least the next two years, and that a new and completely revised CoP for electron beam dosimetry was published in the December issue of *Physics in Medicine and Biology*.

David Burns

Dr. Burns presented the results of a series of measurements made at the BIPM which compared the absorbed dose to water in Cobalt-60 derived from the application of TRS277 to that derived from the BIPM's ionometrically based absorbed dose to water standard. This exercise had been carried out for a large number of chambers of several different types. The spread in values for each chamber type was satisfactorily small. On the average the ratio, here expressed as D_w(BIPM)/D_w(TRS277), was 1.008 i.e. a 0.8% discrepancy, which is unexplained.

DB had until recently worked at the NPL in the UK. He had been responsible for the development of an absorbed dose to water calibration service for electron beams, based on a radically different design of graphite calorimeter; this new service is at an advanced stage of development and a pilot study in UK RT clinics is about to be undertaken. Thus in future curves of $N_{D,w}(Q)$ for electron beams will be offered, with R_{50} being used as the sole quality specifier at the reference depth, defined by z_{ref} (cm) = 0.6 R_{50} (cm) - 0.1. The work at NPL, in collaboration with NRCC (Ottawa), has shown that the stopping-power ratio, $s_{w,air}$, for a wide range of clinical electron beams is well specified as a function of R_{50} at the above reference depth.

M. Saiful Huq

Dr. Huq outlined the progress made in North America (USA and Canada) on the development of a completely new AAPM dosimetry protocol based on absorbed dose to water standards. The new formalism will be based on $k_{Q,Co\text{-}60}$ where the quality Q can be any high-energy photon or electron beam. The draft of the new AAPM protocol gives the theoretical expression for $k_{Q,Co\text{-}60}$ which involves only stopping-power ratios and perturbation factors for Co-60 and the user's quality Q. It is assumed that (W/e) is independent of radiation quality.

The quality specification of high-energy photon beams will be made in terms of $\%dd(10)_X$, the percentage depth-dose **due solely to the x-ray beam** at 10 cm depth in water, which must be derived from the experimentally measured %dd(10) which in practice will be influenced by electron contamination at D_{max} .A universal fit has been made to measurements on clinical beams relating the above two quantities. This led to a long and passionate discussion on the merits or otherwise of the universally used quality specifier $TPR_{20/10}$. It was finally concluded that its replacement by %dd(10) or any other alternative scheme would not result in any significant (i.e. > 0.5%) improvement in dosimetric accuracy.

The possibility of a $N_{D,w}$ obtained from a calibration in an electron beam is allowed for. This complicates the formalism as the precise quality of this calibration electron beam, for instance at NRCC where they have a linac, has not been specified. The quality specification of the electron beam will be made using the same procedure as at NPL for their yet-to-be-launched absorbed-dose-to-water service for electron beams (see the contribution by Dr. Burns).

The AAPM Task Group (TG) will issue the new protocol as two separate papers, published back-to-back in *Medical Physics*, one of which will simply contain the *cookbook* recipe with no theory whatsoever. All the theoretical background will be contained in the second paper.

SH stressed that the proposals for electron-beam based $N_{D,w}$ calibrations were extremely preliminary and had not yet been collectively discussed by the AAPM TG members.

SUBSTANTIVE DISCUSSIONS ON THE WAY FORWARD

The CT continued with wide-ranging discussions on the need for a new IAEA CoP based on ADWS and, if so, how this new document should be structured and exactly what its scope should be.

A summary of these discussions:

This phase of the CT began with a short presentation from the IAEA's Dosimetry Section by Mr. Ladislav Czap (from the lab. In Seibersdorf) on the experimental measurements at the IAEA Dosimetry Laboratory at Seibersdorf of the ratio of $N_{D,w}$ (exp)/ $N_{D,w}$ (TRS277) at Cobalt-60 where the TRS values involved p_{dis} taken from Johansson *et al* (1978). The compilation included many separate measurements using chambers such as the 2561, 2571 and 2581. The spread in values was rather large, especially for the 2571, where it was of the order of 1%.

These results provided part of the case for switching to an absorbed dose to water calibration method.

VS set out all the various options:

1. No change
2. Postpone any decision for 2 to 5 years
3. Produce new version of TRS277 based solely on N_K .
4. Produce a new IAEA CoP which includes both the N_K and $N_{D,w}$.routes.
5. Produce a new IAEA CoP based on $N_{D,w}$.

PA stressed again that the new edition of TRS277 does finally include the major changes (up to 10% in extreme cases) to the data for kV x-ray dosimetry as given in the SSDL Newsletter #31 and also in TECDOC-897. VS welcomed this but thought that TRS277 was a difficult document to find one's way around in.

With regard to the present unsatisfactory spread in $N_{D,w}$ for a given chamber determined by the various PSDLs in Cobalt-60 beams, PA suggested that in the interim period before this spread had been reduced the same **average** value could be disseminated. everywhere in the world. This would eliminate the entirely artificial differences in absorbed dose to water determinations (at Cobalt-60) that would otherwise result in countries with PSDLs who had developed their own standards. Such a mean value could be arrived at by several different means e.g. *weighted* and this was something that would need to be discussed by the CCEMRI.

After some further discussion it was agreed unanimously to rule out Option 4.

VS felt that Option 5 was inevitable even if his country (New Zealand) would not adopt this for some considerable time. He realised that the current situation was untenable i.e. that various countries are going their own way on ADWSs; this was similar to the mid-80s with respect to the use of air-kerma standards.

It was then unanimously agreed that Option 5 should be followed.

PA suggested that the next step was to start analysing the data to determine if a new IAEA CoP based on $N_{D,w}$ is actually feasible at the present time. He wrote down the radiation modalities he would like the new CoP to cover:

1. Cobalt-60 gamma- and megavoltage x-rays,
2. Electrons,
3. Protons,
4. Heavy ions,
5. Medium-energy x-rays (>100 kV),
6. Low-energy x-rays.

The basic expression would be as follows:

$$D_w = M_Q N_{D,w,\,ref}\, k_Q$$

AN said that he would like to see k_Q written as $k_{Q,ref}$ in order to make explicit the fact that the reference radiation will not always be restricted to Cobalt-60.

VS set out further possible *routes* for deriving D_w the absorbed dose to water:

a) $M_Q N_{D,air}\ (s_{w,air})_Q \prod_i (p_i)_Q$

or

b) $M_Q\, N_{D,w}\, k_Q$

or

c) $M_Q\, (N_{D,w})_Q$

where c) is the case corresponding to the Standards Laboratory providing $N_{D,w}$ at a range of different qualities (as the NPL currently does for high-energy photons).

KH made it clear that he strongly favoured just ONE instrument and ONE calibration factor.

AN wondered if the new IAEA CoP needed to include the possibility of a reference radiation other than Cobalt-60 as those countries providing such linac-based calibrations could be assumed to issue their own detailed CoPs, such as the UK, the USA and Canada (AAPM) and Germany.

VS raised the question of calculated or measured k_Q .

PA said that this was a **very** difficult issue.

DB preferred the notation $N_{D,w,ref}$ and $k_{Q,ref}$ as this would leave some flexibility in the new system but KH argued against such a flexible formalism as one would then lose simplicity, which was an essential element of the move to absorbed dose to water standards.

It was generally agreed that one thing to definitely avoid was the creation of a *calculated* $N_{D,w,Co}$ based on a *measurement* of $N_{D,w,ref}$ at a non-Cobalt quality. This would then no longer correspond to the original definition of $N_{D,w,Co\text{-}60}$. This was analogous to the situation in TRS277 where the correction for the central electrode had been included elsewhere in the formalism and thus the original meaning of $N_{D,air}$, i.e. as the absorbed dose to the air in the cavity per meter reading, had been corrupted; this was one of the items that had been corrected in the new IAEA CoP for plane-parallel chambers, TRS381.

The next discussion concerned how calibrations performed in electron beams could be handled from the point of view of the formalism. This was not all clear for some time. Finally, AN made the following suggestion:

There could be 3 alternative routes:

A. The PSDL/SSDL supplies $N_{D,w}$ (for a particular chamber) solely for Cobalt-60. The CoP gives values of k_Q for that chamber (from either theory or experiment). The dose to water is then given by;

$$D_w = M_Q N_{D,w,\, Co\text{-}60}\; k_{Q,Co\text{-}60}$$

B. The PSDL/SSDL supplies $N_{D,w}$ (for a particular chamber) for Cobalt-60 and for one or more other qualities e.g. electrons. The CoP gives values of $k_{Q,Co\text{-}60}$ for that chamber (from either theory or experiment) as in A but also gives the theoretical expression for $k_{Q,ref}$ in order that an (inevitably theoretical) value appropriate to the user's quality Q and the (in principle arbitrary) non-Cobalt reference quality *ref* can be calculated. The dose to water is then given by;

$$D_w = M_Q N_{D,w,\, ref}\, k_{Q,ref}$$

C. The PSDL/SSDL supplies a curve of $N_{D,w,Q}$ (for a particular chamber) as a function of the quality specifier, covering the complete range of user qualities. No values of k_Q are needed. The dose to water is then given by;

$$D_w = M_Q N_{D,w,\, Q}$$

This division into 3 distinct categories led to a long and vigorous discussion. Finally it was accepted by all the consultants that these three categories were not really distinct. Both A and C were special cases of B.

The final point to be resolved was the coverage of the new CoP in terms of the various radiation modalities. Again, a great deal of discussion ensued. It was finally unanimously agreed to include **all modalities** mentioned above. As far as the members of the CT were aware, however, **neutrons**, could not be included as it was not possible to base the dose determination on the use of just one single ionization chamber. However, none of the CT members were neutron dosimetry specialists and it was conceded that the above tentative conclusion could well be revised in the light of more complete information.

A further decision was made to include guidelines on dose measurements in **non-reference conditions** i.e. the complete depth-dose curve, different off-axis distances etc.

The remainder of the time was then devoted to sketching AN OUTLINE OF THE STRUCTURE AND CONTENTS OF THE NEW CoP (see below).

OUTLINE OF THE STRUCTURE AND CONTENTS OF THE PROPOSED NEW IAEA CoP

ABSORBED DOSE DETERMINATION BASED ON STANDARDS FOR ABSORBED DOSE TO WATER FOR EXTERNAL BEAM RADIOTHERAPY; AN INTERNATIONAL CODE OF PRACTICE

Foreword

CONTENTS

1. INTRODUCTION - Set context - need, scope, limitations

2. DEFINITIONS - Full definition of symbols and terms used

3. FORMALISM - Based on general equation: $D_{w,Q} = M_Q \; N_{D,w,Q0} \; k_{Q,Q0}$

4. IMPLEMENTATION

4.1 General

k_Q -measured (for individual chamber) vs experimental (for chamber type) vs theoretical
$N_{D,w}$ - ^{60}Co vs other reference qualities
M_Q - influence quantities, general equipment

4.2 Measurement Chain

IMS, PSDL, SSDL, users (diagrams)

5. HIGH ENERGY PHOTONS

Repeat basic expression
Beam quality specification (use of $TPR_{20/10}$ recommended)
Reference conditions
k_Q values — if measured (for individual chamber), use values supplied
if experimental (for chamber type), go to data tables
if theory, go to data tables
Non - ^{60}Co
Non-reference conditions (relative measurements)
Data (experimental values for k_Q, stopping power ratios, perturbation factors, etc)
Worksheet
Uncertainties

6. ELECTRONS - Repeat as for Section 5

7 KILOVOLTAGE X-RAYS

7.1 General

Quality range definition
Phantom versus in-air

7.2 Medium Energies

Repeat as for Section 5

7.3 Low Energies

Repeat as for Section 5
(emphasis on: boundary 2mm Al, non-reference conditions, HVL determination)

8. HEAVY CHARGED PARTICLES

8.1 Protons

8.2 Others

References

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REPORT OF THE FIRST RESEARCH CO-ORDINATION MEETING (RCM) FOR THE CO-ORDINATED RESEARCH PROGRAM (CRP E2-RC-641) ON: DOSE DETERMINATION WITH PLANE-PARALLEL IONIZATION CHAMBERS IN THERAPEUTIC ELECTRON AND PHOTON BEAMS.

2-5 December 1996

IAEA Dosimetry Section, Vienna

External Participants were
Ms. Graciela VELEZ (ARGENTINA)
Ms. Ann VAN DER PLAETSEN (BELGIUM), Ph.D
Mr. Martin ROOS (GERMANY), Ph.D.
Ms. M[a]. Cruz LIZUAIN (SPAIN)
Mr. Håkan NYSTRÖM (SWEDEN), Ph.D.

Participants from IAEA were:
P Andreo (PA) [scientific secretary]
L Czap (LC)
G Matscheko (GM)
K Zsdansky

SUMMARY

The present status of the contributions to the CRP was presented by the participants and the material was discussed in detail. Since the achievable uncertainties depend strongly on the performance characteristics of the chambers available, the investigation of the accuracy of the new data and procedures extends from the investigation of basic mechanisms to chamber-to-chamber variations influencing the applicability of procedures and the resulting uncertainty in dose determination.

Some of the central topics are: A comparison of the absorbed dose values, obtained using different chamber types in the framework of TRS-381 with the results of an independent dosimetrical method, a comparison of results obtained at various accelerators using different chamber types and applying different calibrations, the determination of the uncertainties of the recommended saturation corrections for various chamber types and irradiation conditions, the investigation of chamber-to-chamber variations of different properties, the correction of the polarity effect, the check of basic data as the relative contribution of electrons liberated in the chamber wall compared with those from the surrounding phantom, the check of the conversion of measurements in plastics to those in water, the investigation of the uncertainty caused by the missing correction for the backscatter deficiency due to the lack of data, determination of the respective data, etc.

An additional central point is the quantification of differences with existing recommendations, including TRS-277, the current AAPM protocols, the new UK IPEMB Electron CoP and the new DIN standard DIN 6800-2.

The various activities of the group were coordinated and a time schedule for the pending investigations was worked out.

SCIENTIFIC BACKGROUND

In 1987, the IAEA published a report entitled "Absorbed Dose Determination in Photon and Electron Beams. An International Code of Practice" (IAEA Technical Reports Series No. 277), to advise users how to obtain the absorbed dose in water from measurements made with an ionization chamber, calibrated in terms of air kerma. For high-energy photons (energies above 1 MeV) the chamber calibration was at a single photon quality (Cobalt-60 gamma rays). The Code of Practice described procedures and provided data to use such ionization chambers to obtain absorbed dose for higher energy photons and also for electron beams. It was so designed that a variety of cylindrical chambers could be used, which represented the existing conditions world-wide. However, most national and international dosimetry protocols recognized the advantages of plane-parallel ionization chambers, explicitly for electron beams and especially low-energy electron beams (below 10 MeV). Although this was acknowledged in TRS-277, the calibration and use of these chambers were not fully developed.

Since the publication of TRS-277 in 1987, various recommendations for the specific procedures for the use of plane-parallel ionization chambers have been published. Additional knowledge about the use of cylindrical chambers has also appeared. Accordingly the IAEA formed an international working group, which met in 1992, to review the status of IAEA TRS-277. The working group, which consisted of P. Andreo (then at the Karolinska Institute, Sweden), K. Hohlfeld (PTB, Germany) and A. Nahum (Institute of Cancer Research, UK), proposed the formation of a consultants' group, to prepare a document in the Technical reports Series on the use of plane-parallel ionization chambers in high-energy electron and photon beam dosimetry. This group (P. Almond, U.S.A.; P. Andreo, Sweden-Spain; O. Mattsson, Sweden; A. Nahum, United Kingdom and M. Roos, Germany) met during 1994 and 1995 to write the report which has been now submitted for publication.

The new Code of Practice both complements and extends IAEA TRS-277. It describes options on how to calibrate plane-parallel chambers, against air-kerma or absorbed dose to water standards at Cobalt 60 gamma ray energies, in order to obtain $N_{D,air}$, the absorbed-dose-to-air chamber factor, or $N_{D,w}$, the chamber absorbed dose calibration factor respectively. The use of these chambers to calibrate therapy electron beams, as well as relative dose measurements for photon and electron beams, is presented. It also updates some of the data and concepts in TRS 277.

SCIENTIFIC SCOPE

The scientific scope of the proposed program is to investigate the accuracy of the new data and procedures included in the Code of Practice. In addition, differences with existing recommendations will be quantified to analyze the possible impact on patient dosimetry.

The RCM was organized to revise the current activities in the CRP and to discuss the following activities:

- to investigate the accuracy of the new data and procedures included in the Code of Practice, comparisons of absorbed dose to water determined under certain reference conditions with detectors and methods that have already shown high accuracy will be undertaken.
- the conditions will then be changed to those where plane-parallel ionization chambers are of special applicability , performing dosimetry in different plastic materials commonly used as dosimetry phantoms.
- comparisons with TRS-277 and dosimetry "protocols" recently issued by different national organizations (AAPM TG-39) will be performed using the different types of detectors (plane-parallel ionization chambers) and phantom materials, mainly plastics, included in the Code of Practice.
- differences with the recommendations above will be quantified to analyze the possible impact in patient dosimetry.

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Dr Mattsson (Sweden) and Mr Alonso-Samper (Cuba) were not present in this first RCM.

STATUS REPORT FROM THE PARTICIPANTS

Ms. Graciela R. Vélez (ARG)

In Argentina there are approximately 16 linacs with capabilities of electron beams. Most of them were installed in the last 4 years. Very few physicists have plane-parallel ionization chambers to perform their measurements and calibrations. Almost everyone works with cylindrical chambers, mainly NE 2571 or PTW(different models). Since the end of 1994 and during 1995 the "population" of pp-chambers were increased; however, still we have only 5 pp-chambers all over the country, all of them are PTW - Markus chambers.

$N^{pp}_{D,air}$ factor determinations for these pp-chambers have been performed following different methods. One of them was calibrated by comparison with a reference cylindrical IC for which $N^{ref}_{D,air}$ was well known, in a 18 MeV nominal energy electron beam, in a water phantom, following the main recommendation of the IAEA TRS-381. However, the reference IC was not a graphite walled and 1mm Al central electrode (as NE2571) but a Capintec PR 06G, which is a plastic walled chamber (C-552), having a 1 mm C-522 central electrode. For this particular plane-parallel ionization chambers, the $N^{pp}_{D,air}$ factor has also been determined following the Co-60 in phantom (water) method. The reference IC was the same as above. The results, although preliminary, were quite good, finding out discrepancies between both $N^{pp}_{D,air}$ factor values of less than 0.5%.

An additional Markus chamber was calibrated using the electron beam method (16 MeV nominal energy) in a PMMA phantom, against a reference chamber NE2571, but we observed some differences in the values of scaling factors used (the AAPM TG-39 scaling factor for PMMA deviates from that in IAEA TRS-381).

Two other plane-parallel ionization chambers have $N^{pp}_{D,air}$ factors determined from N_k reported by the Regional Reference Center (CRR - Ezeiza - CNEA;SSDL), using a Co-60 beam. For these two chambers there was some confusion concerning the reference conditions for the N_k given by the laboratory. It would be necessary to clarify this point.

The Argentine Society of Medical Physics (SAFIM) organizes since 1993 annual meetings to perform Dosimetric Intercomparisons between several users, promoting the implementation of the IAEA TRS-277. As a result of these meetings, the differences between users in performing dose measurements were becoming smaller, and an improvement was observed in the discussions on perturbation factors. This year, we compared the results obtained using pp-chambers with different calibrations and cylindrical IC to determine the absorbed dose to water in a 10 MeV nominal energy electron beam; in all the cases following the recommendations of the IAEA TRS-381. This promotes practical implementation of the IAEA Code of Practice particularly for electron beam calibrations and discouraged the use of the AAPM TG-39 in this field. The main reason for was that the users have achieved good results in the implementation of TRS-277 for photon beams whereas the use of TG-39 causes some kind of "data mix", resulting in non desirable mistakes and, of course, errors in dose determinations. The preliminary results were good, taking into account that 4 of the 5 pp-chambers existing in the country were able to participate (unfortunately the fifth presented electrical problems at the time of measurement). There was good agreement between values obtained by cylindrical IC and plane-parallel ionization chambers (the discrepancies were less than $\pm$ 0.8%).

Dr. Ann Van der Plaetsen (BEL)

- Relative dose measurements were performed in the electron beams of a Philips SL18 accelerator using a p-type diode, a diamond detector and a plane-parallel Markus ionization chamber. Values obtained for the depth of maximum dose in a 10 cm x10 cm field of electrons with nominal energies

4, 6, 8, 10, 12, 15 and 18 MeV with the different detectors were in agreement. Comparison of values of d_{max} obtained with the Markus chamber in water and in a PMMA phantom showed agreement with the scaling method in TRS 381. The electron parameters R_{50} and R_p were determined for a 14 cm x14 cm field. Again agreement was obtained for the diode and diamond detectors. One should be aware that the diamond detector needs to be pre-irradiated with a rather high dose to yield reliable results.

- The determination of E_0 based on R_{50}^{D} measured with a diode, and R_{50}^{J} measured with the Markus chamber resulted in a maximum deviation of 0.4% for the derived stopping power ratios.
- The $N_{D,air}$ determinations for the Markus chamber were performed in the 18 MeV electron beam by comparison with the NE 2571 and the PTW 30001 cylindrical ionization chamber, in a water and in a PMMA phantom. The resulting $N_{D,air}$ factors were within 1% in agreement with the $N_{D,air}$ factor calculated from the air kerma calibration factor in ^{60}Co. However, differences between consecutive measurements with the same chambers pointed out the need for an external reference monitor detector in the beam.
- Experimental determination of the correction factor h_m to correct for the difference of fluence in PMMA and in water were performed with the NE 2571, the PTW 30001 and the plane parallel Markus chamber. Values for this correction factor smaller than one were obtained for all energies in contradiction to those specified by the IAEA protocol. Further investigations are needed.

Dr. Martin Roos (GER)

The investigations by M. Roos are focused on the following tasks:

1. Investigation of the saturation behavior of plane-parallel chambers in pulsed, non-scanned beams: evaluation of the uncertainties introduced by the application of the Boag formula for volume recombination.
2. Determination of the polarity effect of various plane-parallel chamber types for electron beams in the energy range 1 MeV to 20 MeV.
3. Experimental determination of the displacement of the effective point of measurement of the Markus chamber from the front surface of the air cavity in electron beams. Evaluation of the resulting dose deviations.
4. Experimental investigation of the influence of the wall material of plane-parallel chambers on the energy dependence of the response in electron beams:

   Construction of plane-parallel chambers of one single design but of different wall materials and with different rear wall thickness. Performance of the measurements in the energy range from about 1 MeV up to 20 MeV (using a 20 MeV linear accelerator and a 5 MeV microtron) in a PMMA phantom and comparison with the results of the “homogeneous set up” (PMMA chamber in PMMA phantom).

Concerning the saturation correction an experimental investigation was presented, showing, that the uncertainties introduced by the application of the Boag formula for volume recombination are usually not larger than about 0.1%. The results showed that the recommendations given in TRS-381 on this subject are reasonable approximations.

It was shown that corrections for the polarity effect may constitute a problem. Since this is essentially a charge balance effect, it depends on the properties of the incident radiation, on the measuring depth and - sometimes quite pronounced - on the field size. A few examples were given. It was demonstrated that for some chamber types the determination of the correction factors seems not realistic in practice, since the stabilization times are too long. It was recognized that these problems cannot be overcome by modified or improved procedures, but exclusively by an improvement of the performance characteristics.

With respect to perturbation effects, the physical background of the in-scattering effect and the displacement effect was discussed. It was shown that deviations of the chamber properties from the desirable values (table 3.1) may not only cause a falsification of the reading by the in-scattering effect, but in addition may shift the effective point of measurement from the front surface of the air volume towards its center. As an example results for the Markus chamber were shown. Measurements in the energy range 6 MeV $\leq E_n \leq$ 20 MeV show a shift of about 0.5 mm, deduced by a comparison with the Roos chamber.

The last part of the presentation concentrated on the selection of stopping power ratios. The selection procedure included in TRS 277 and TRS 381 and the virtual initial energy method included in the new DIN standard DIN 6800-2 were compared with the results of the MC simulations by Ding et al. It was shown that - similar to the examples given already in TRS 381 - the DIN method enables a slightly better agreement with the MC results. In all cases, however, the deviations are within a reasonable order of magnitude.

Ms. M. Cruz Lizuain (SPA)

Determinations of chamber factors, $N_{D,air}$, and absorbed dose to water, D_w, have been made according to the new IAEA TRS-381 Code of Practice for dosimetry with plane-parallel chambers. Results of these quantities have been compared to those obtained according to the recommendations in the IAEA TRS-277 CoP and the AAPM TG-39 protocol.

$N_{D,air}$ factors have been obtained for a cylindrical chamber NE-2571 and two plane-parallel chambers, NACP-02 and PTW (Markus). The determinations of $N_{D,air}$ for the plane-parallel chambers, have been made following the methods recommended in TRS-381 based on “in phantom” measurements in electron and ^{60}Co beams. The difference between the $N_{D,air}$ values obtained with these two methods was about 0.5%. For the electron beam method, the comparison with $N_{D,air}$ obtained with TRS-277, yielded differences smaller than 0.5% which were basically caused by the difference between $p_{cel\text{-}gbl}$ (TRS-277) and $p_{cel}\,k_{cel}$ (TRS-381). In the case of TG-39, and in spite of the differences in various physical quantities and factors ($s_{graphite,air}$ at Co-60, W/e, b_{wall}, etc) most discrepancies cancel out and the factors for the two plane-parallel chambers were within 0.5% for the two protocols.

The absorbed dose to water under reference conditions has been determined using several combinations of ionization chambers (cylindrical and plane-parallel) and phantoms (water and PMMA), following the recommendations of the three protocols. The measurements were performed in electron beams of nominal energy range from 4 to 18 MeV produced by two Varian accelerators, Clinac 18 and Clinac 2100C. The effective point of measurement for the chambers was placed at the depth of maximum dose rate. All measurements were corrected for polarity and recombination effects. The absorbed dose to water was determined according to TRS-381 and compared with the recommendations in TRS-277 and TG-39. Ratios were plotted as a function of the mean energy at depth, E_z , as shown in the attachment.

When the measurements were made in water phantoms, the differences between the three protocols were within 1% for all the chambers. A significant difference (up to 3%) was found, however, between the absorbed dose values obtained using the TG-39 and TRS-381, when the measurements were made in PMMA phantoms. This disagreement was mainly caused by the different scaling procedures plastic/water used in the two protocols (C_{pl}), the fluence correction factor (h_m), and the mean restricted mass stopping power ratio ($s_{w,air}$) in TRS-381 versus the product of $s_{PMMA,air}$ by the ratio of mean unrestricted mass collision stopping power of water to PMMA ($s_{w,PMMA}$) recommended in AAPM TG-39.

Dr. Håkan Nyström (SWE)

In calibration procedures for pp-chambers in ^{60}Co beams knowledge of either $k_m k_{att}$, in the case of a kerma calibration or $p_{wall,pp}$ in the case of a dose to water calibration, is needed. Numerical values for the NACP chamber in the literature are conflicting, therefore a systematic investigation was undertaken to check chamber-to-chamber variations in the $p_{wall,pp}$ factor for a large number (35) of NACP-chambers. All the investigated chambers were produced during the period 1994-1996 and were borrowed directly form the manufacturers and were hence not previously used. It turned out that the p_{wall} for individual chambers from the same manufacturer did not show significant variations. However, the p_{wall} values of NACP chambers by two different manufacturers showed a significant difference. It was concluded that the investigation would benefit from additional data from older NACP-chambers. Differences in p_{wall} due to changes in production methods etc. over the years can in this way be detected. Also individual differences in ion recombination properties were investigated. Care has to be taken in the application of the "two voltage method" not to introduce additional uncertainties.

Since the amount of data on recombination in scanned electron beams is rather scarce, data on this topic were presented and it was stressed that additional investigations would be desirable.

The α-factor, appearing in the expression for p_{wall} as well as for k_m was discussed. The need for validation of the experimental values by Lempert et al. from 1983 was pointed out.

SUMMARY OF THE DISCUSSIONS AND CONCLUSIONS

A number of topics were discussed as a result of the presentations.

* The factors p_{cav} and h_m and their relation for different plastic materials should be further investigated. The present assumption that p_{cav} is independent of phantom material should be checked or validated. Some presented results for h_m in PMMA was in conflict with the factors in TRS 381 and should be studied. It was proposed that every participant of the group should measure h_m for as many chamber types and plastics as possible.
* Scaling results from measurements in plastic to water are done in different ways in different protocols. There is a need for further tests with various plastic materials and also in the context of comparisons between different dosimetry protocols.
* The N_D factors for a plane-parallel ionization chambers obtained at different occasions can give different results. The cause for such discrepancies were discussed and the need for external monitors during the calibration process was emphasized. The influence in $N_{D,air}$ by using different cylindrical chambers was discussed and it was agreed that further investigations in this respect should be performed.
* The effective point of measurement does in some type of plane-parallel ionization chambers tend to move towards the center of the chamber at larger depths. The reason for this effect and the constructional implications were discussed.
* Methods for ion recombination corrections were reviewed and discussed in some detail. In the extreme case of scanned, pulsed electron beams, more data would be welcomed.
* The polarity effect are in some chambers severe. In some cases the stabilization time may be of the order of hours. It was concluded that there are no ways to avoid this effect; it is more of a constructional problem for some chambers. Detailed data for a variety of chamber would be useful to analyze the magnitude of this problem.
* In the calibration procedures for plane-parallel ionization chambers including ^{60}Co beams chamber

specific factors like k_m k_{att} or p_{wall} are needed. p_{wall} values fore a large number of NACP chambers showed that the chamber-to-chamber variations are small but can be significant for chambers from different manufacturers. As the tested chambers all were produced during a short period of time, it was agreed that data should be added also for older chambers, manufactured several years ago.

* The use of diamond detectors and diodes for relative dose measurements were discussed in some detail.
* The possibilities and advantages of using the Fricke dosimeter as a completely independent dosimetry system to test the TRS 381 was discussed. It was generally believed that it would be of great interest to include such measurements. Practical details like vessel types etc. were discussed.
* The application of the protocol for extreme “non-reference conditions” such as very small fields or intra operative radio therapy fields were discussed. A general opinion was that these situations at least partly lies beyond the scope of this work.
* The need of comparing the present protocol with other protocols in use were discussed. It was agreed that such comparisons constitute an essential part of this groups work. The protocols most essential to compare with are TRS 277, TG 39, DIN 6800-2 and the IPEMB Electron CoP issued. Particularly in the case of older protocols, great care has to be taken to avoid mixing of factors, numbers and methods from different protocols; i. e. to be consistent. In the case of more recent protocols the methods and their possible impact on the result, rather than the numbers should be focused. As not all possible aspects of the different protocols and all possible combination of e. g. geometries and energies can be covered, special topics, for example scaling in plastics or high energy electrons should be selected.

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