NORDISK RAPPORTSERIE OM STRÅLSKYDDSFRÅGOR

No. 8

Nordic dosimetric capabilities
Resources, needs and plans

REPORT ON NORDIC
RADIATION PROTECTION CO-OPERATION

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RADIATION PROTECTION CO-OPERATION

No. 8

Nordic dosimetric capabilities

Resources, needs and plans

The radiation protection and nuclear safety authorities in

Denmark, Finland, Iceland, Norway and Sweden

Statens strålevern

Norwegian Radiation Protection Authority

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Report on Nordic radiation protection co-operation

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Foreword

A ”Chefsmöte” has requested a description of the dosimetric competence in field of ionising radiation from the Nordic dosimetry working group.

Minutes from the Nordic Chefsmöte (CM) in Finland 9 - 10 June 2004 at Haikon Kartano, Finland, agenda item 2, radiation dosimetry:

“It was recognised that co-operation in the field of radiation dosimetry within the Nordic countries is useful and important. However, it was concluded that it would be useful for the CM to have better information of the overall situation. Therefore, the WG should prepare a report describing the activities and capabilities to calibrate various measuring devices in the national laboratories in each of the Nordic countries, including the present situation, future plans and priorities. The report should cover activities on the national standards, as well as, on quantities of activity such as radon calibration.”

The dosimetry group reports here on the capabilities in the dosimetry, both calibration capabilities and on site dosimetry audits. Research and developments in dosimetry are as well included. The dosimetry working group has collected information on dosimetry in all the Nordic countries. It mainly deals with the capability of calibration, which means making dosimeters available for measurements in SI units and with traceability to Primary Standard Dosimetry Laboratories (PSDLs). At the moment no laboratory operates at primary level, all are Secondary Standard Dosimetry Laboratories (SSDLs).

In the field of measurement of activity this report will only give some information on radon. Other needs for activity measurement standards are coming from the nuclear medicine, the environmental activity measurements (marine and terrestrial), waste, disposal, research and for radiation protection. These needs are not dealt with in this report on a Nordic level. Some countries have, however, given comments on their situation in this field.

1 Summary

Ionising metrology laboratories support directly the authority activities and competence in each country. SSDLs are essential to assure a reliable and unbroken chain of dosimetry from primary laboratory to the end user.

The competence and capabilities in dosimetry in the Nordic countries are described in the present report. Dosimetry contains the following elements:

1. Calibrations of dosimeters in standard laboratory.
2. Methods of applied dosimetry like clinical dosimetry at hospitals, x-ray diagnostic and radiation protection.
3. Research and development on both standard and applied dosimetry and research in health effects of radiation.
4. Dosimetry used in regulatory work and licensing. Dosimetry audits in radiotherapy.
5. Education and training in dosimetry for medical physics, nuclear energy, particle physics and radiation protection.
6. International cooperation like IEC working groups, IAEA commissions, ICRU- and ICRP-work.

Since twenty years the strategy for the Nordic SSDLs has been to maintain the national standards at the secondary level i.e. with calibrated ionisation chambers. Targets are given in the EUROMET roadmaps for radiation metrology research and development (RD). It is recommended to link dosimetry and the increased needs for it closed to RD and to communicate this and the EUROMET RD work to the Nordic universities and research environments.

The IAEA guidelines and criteria for an SSDL are described in the IAEA SSDL network charter on the background of safety and security needs stressed in the International Safety Standard for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS). The Nordic dosimetry laboratories are members of the IAEA SSDL network.

A total of 19 persons are working in the Nordic dosimetry field in the Nordic countries. The services and competence in the dosimetry is given in the report, but the description is not complete for any of the countries.

In addition to the experimental dosimetry, dosimetry simulations based on calculation techniques i.e. Monte Carlo calculations are important. In dosimetry these simulations of radiation are valuable for controlling correction factors determined by measurements or theoretical calculations.

For training and sharing the dosimetric expertise a Nordic cooperation is of great importance. A first Nordic workshop was organised at SSI in June 2006.

2 Introduction

The dosimetry is the theory and use of principles and techniques in the measurement of doses from ionising radiation. The Nordic radiation protection institutes were founded on the base of work in dosimetry. Many dosimeters and the theory of dosimetry were created in these institutes. In the 1970ies the Secondary Standard Dosimetry Laboratories (SSDLs) of the Nordic countries were established. After many years of "primary dosimetry" using free air chambers, the laboratories replaced the primary standards with ionisation chambers calibrated at Bureau International de Poids et Mesures (BIPM), National Physical Laboratory (NPL) or Physikalisch-Technische Bundesanstalt (PTB). A short history of the Nordic dosimetry is given in Appendix 1.

Radon measurements started in mines where workers suffered from lung cancer. In the late 1970ies, high radon concentration in indoor air was reported and countrywide measurement programs started in the Nordic countries in the 1980ies.

The Metre Convention (Convention du Mètre) was signed by the Nordic countries in 1875 and 1923 (Finland). More about BIPM and the Consultative Committee for Ionizing Radiation (CCRI) is given in Appendix 2.

At a meeting held in Paris on 14 October 1999, the directors of the National Metrology Institutes (NMIs) of thirty-eight Member States of the Metre Convention and representatives of the International Atomic Energy Agency (IAEA) and the Institute for Reference Materials and Measurements (IRMM) signed a Mutual Recognition Arrangement (MRA). See Appendix 3 for details.

In Europe the responsible organization for implementing the MRA is the European Collaboration in Measurement Standards (EUROMET). EUROMET is a cooperative voluntary organisation between national metrology institutes (NMIs) in the EU and EFTA, including the European Commission. IAEA, BIPM and IRMM are also members of EUROMET. In the Nordic countries the dosimetry laboratory of Denmark, Finland, Norway and Sweden are NMIs. They each have a designated Contact Person (CP) that takes part in the annually EUROMET Ionising Radiation Technical Committee (TC-IR) CP-meeting. For details see Appendix 3.

In 1976, IAEA together with the World Health Organization (WHO) established a network of SSDLs, known as the IAEA/WHO SSDL Network. An SSDL is a laboratory which has been designated by competent national authorities to undertake the duties of providing the necessary link in the traceability of radiation dosimetry to national/international standards for users within that country. An SSDL is equipped with secondary standards (ionisation chambers) which are traceable to the Primary Standards of Dosimetry Laboratories (PSDLs). Denmark, Finland, Norway and Sweden joined the SSDL network in the 1970ties. The SSDLs function is to fulfil a nationwide metrological function based on traceability to approved measurement standards. The requirements for the status as an SSDL in the IAEA/WHO SSDL Network are given in Appendix 4.

Beside calibration one of the main tasks of the SSDLs is the dissemination of codes of practice, guidelines or protocols, for the dosimetry of external beams used in radiotherapy, Brachytherapy, diagnostic x-ray and radiation protection.

This report outlines the status on standard dosimetry in the Nordic countries in 2006.

3 Needs for dosimetry and radon measurements

All the Nordic national metrology laboratories for ionising radiation are operating as a part of the national radiation protection institutes. The main reasons for this arrangement are the wide use of experimental dosimetry by the radiation protection institutes, availability and maintenance of expertise on dosimetry in a country and in an institute, and the fact that calibrations for ionising radiation is generally not a profitable business. The competence in dosimetry contains the following elements:

1. Calibrations of dosimeters in standard laboratory.
2. Methods of applied dosimetry like clinical dosimetry at hospitals, x-ray diagnostic and radiation protection.
3. Research and development on both standard and applied dosimetry and research in health effects of radiation.
4. Dosimetry used in regulatory work and licensing. Dosimetry audits in radiotherapy
5. Education and training in dosimetry for medical physics, nuclear energy, particle physics and radiation protection.
6. International cooperation like IEC working groups, IAEA commissions, ICRU- and ICRP-work.

The Nordic laboratories have maintained their standards for twenty-five years at the secondary level. This strategy has been well justified as the uncertainties by the end users are not increased markedly due this arrangement and the costs to operate secondary standards rather than primary standards are much lower. Primary standard instruments are recently used mainly for research and development purposes in the Nordic countries.

A specific feature for maintenance of the standards (both the primary and the secondary) for dose quantities of ionising radiation is that the accuracy achievable at the laboratory is relatively close to the required accuracy in the applications. E.g. in radiotherapy 1% uncertainty can be achieved in a laboratory and 1 – 2% uncertainty is required for the dose in a radiotherapy linear accelerator beam at the reference measurement conditions. Even for radiation protection quantities the accuracy achievable in the laboratory is only about 10 percent lower than the needed accuracy. For most other physical quantities the situation is totally different. This emphasises the importance of reliable dissemination of calibrations to the users and laboratories delivering calibrations for users in this field have to work close to the users, especially in field of medical applications.

In the following, each country gives a short description of the need for competence in dosimetry for its country. The calibration services and tests in the dosimetry laboratories are the main sources for the competence and are therefore given the highest priority in the description. Background information on number of appliances is given to show the dosimetry scope.

3.1 Denmark

Denmark has only one accredited laboratory for Ionizing Radiation, the High Dose Reference Laboratory (HDRL Risø), and offering calibration services for industrial users. In Denmark NIRH is a member of the SSDL Network and offers calibration of instruments used in Radiation Therapy according to the Legislation. Although not accredited Denmark also have services for Personal Dosimetry.

For many years NIRH has participated in the calibration of Activity Meters (Dose calibrators) for measurements of the *Activity* of radioactive materials used in Medicine (see e.g. CCRI(II)-K3.F-18 comparison Final report, G Ratel et al 2005 *Metrologia* 42 06007) but this work has now ceased due to the requirement for accreditation.

The number of radiation appliances and radionuclide laboratories are presented in tables 1 and 2 below.

Table 1 Number of radiation appliances and radionuclide laboratories used in health care and veterinary X-ray practices at the end of May 2006 in Denmark.

Appliances/laboratories	**Number**
X-ray diagnostic appliances (generators)	1393
Dental X-ray appliances	5660
Radiotherapy accelerators	37
Radiotherapy afterloading appliances	7
X-ray therapy appliances	74
Appliances containing radioactive substances	86
Veterinary X-ray appliances	438
Radionuclide laboratories	151

Table 2 Number of radiation appliances and sources, and radionuclide laboratories in industry, research and education at the end of May 2006 in Denmark.

Appliances/laboratories	**Number**
Appliances containing radioactive substances	3100
X-ray appliances and accelerators	743
Radionuclide laboratories	833

3.2 Finland

Of all the calibrations and irradiations performed by the Radiation Metrology Laboratory of STUK 30 – 40 percent are for the STUK internal use i.e. measurement activities related to the regulatory activities or research. The main customers for calibration services outside STUK are the Finnish nuclear power companies, hospitals, domestic manufacturers of survey dosimeters (Rados Technology and KATA electronics), manufacturers for medical X-ray equipment (Planmega, Planmed, GE), a company manufacturing equipment with sealed sources for prosess technology (Metso Oy) and a company offering personal dosimetry services (Doseco Oy).

Finland has no accredited laboratories or companies offering calibration services for dosimeters of ionising radiation. KATA electronics offers services for periodic checks for survey meters and Doseco Oy has accredited dosimetry measurement services for personal dosimetry.

The number of radiation appliances and radionuclide laboratories are presented in tables 3 and 4 below.

Table 3 Number of radiation appliances and radionuclide laboratories used in health care and veterinary X-ray practices at the end of 2004 in Finland.

Appliances/laboratories	Number
X-ray diagnostic appliances (generators)	1566
Dental X-ray appliances	5147
Radiotherapy accelerators	30
Radiotherapy afterloading appliances	12
Appliances containing radioactive substances	99
Veterinary X-ray appliances	223
Radionuclide laboratories	71

Table 4 Number of radiation appliances and sources, and radionuclide laboratories used in industry, research and education at the end of 2004 in Finland.

Appliances/laboratories	Number
Appliances containing radioactive substances	6225
X-ray appliances and accelerators	841
Radionuclide laboratories	176

For radiotherapy, all Finnish hospitals send their dosimeters to STUK for calibrations every three years. For a user the calibrations at a Radiation Metrology Laboratory of STUK are not compulsory as only traceability to international measurement system is required. Traceability is stated as calibrations in national standard laboratory under MRA or in an accredited dosimetry laboratory. Still, the users in radiotherapy and also in diagnostic field have found the STUK services most convenient.

Generally it has been found important to have a strong Radiation Metrology Laboratory at STUK that also takes care of secondary standards nationally. The work in the Radiation Metrology Laboratory is important for sustaining the necessary knowledge on measuring radiation and it also serves for training new staff for various tasks at STUK.

STUK carries out indoor radon measurements in connection with indoor radon research and also as measurement services. In both tasks quality assurance and calibration are essential. The measurement service that provides passive integrating radon dosimeters has been accredited. Continuous control of these dosimeters against a secondary standard radon monitor is part of the quality control. STUK has calibrated its secondary standard radon monitor biannually at the primary standard laboratory PTB (Physikalisch-Technischese Bundesanstalt) in Germany. STUK has also provided calibration services for companies which have needed periodical calibration of their radon monitors. These calibrations have been performed using the secondary standard monitor of STUK.

3.3 Iceland

Iceland does not have a Secondary Standard Dosimetry Laboratory. Meters used by the Icelandic Radiation Protection Institutes (Geislavarnir ríkisins, GR) are sent regularly for calibration abroad. Constancy checks are performed twice a year, using the institutes X-ray diagnostic unit. Quality audits and calibrations for the therapy-units have been performed by agencies outside of Iceland.

Radiation therapy is only performed at Landspitali University Hospital. The therapy-unit is audited by the Norwegian NRPA and regular calibrations of associated ionization chambers are made by the Swedish SSI or other accredited bodies.

Cooperation in the field of dosimetry between Geislavarnir and SSI was established in 2006 following the workshop in Sweden.

A closer cooperation with the other Nordic countries in this field is being planned, starting this summer with the workshop in Sweden.

Table 5 The number of radiation appliances and radionuclide laboratories used in health care and veterinary X-ray practices at the end of 2005 in Iceland, approximately.

Appliances/laboratories	Number
X-ray diagnostic appliances (generators)	132
Dental X-ray appliances	368
Radiotherapy accelerators	2
Radiotherapy afterloading appliances	1
Veterinary X-ray appliances	17
Radionuclide laboratories (A or B type)	4

No Icelandic companies provide calibration service for dosimeters of ionizing radiation.

A growing need is felt for a national calibration service in diagnostic applications (Dose Area Product (DAP) and Dose Length Product (DLP)).

3.4 Norway

In Norway the SSDL at NRPA calibrates dosimeters from the hospitals, the universities and the companies. The NRPA inspection and auditing dosimeters are calibrated in the institution. The personal dosimetry services in Norway at NRPA and the Institute for Energy Technology (IFE) are calibrated by NRPA.

The number of radiation appliances and radionuclide laboratories are presented in table 6 below. Numbers representing the use of radiation medical health care are given in table 7.

Table 6 The number of radiation appliances and radionuclide laboratories used in health care and veterinary X-ray practices at the end of 2005 in Norway, approximately.

Appliances/laboratories	Number
X-ray diagnostic appliances (generators)	1000
Dental X-ray appliances	4000
Radiotherapy accelerators	35
Radiotherapy afterloading appliances	4
Veterinary X-ray appliances	200
Radionuclide laboratories	25

Table 7 The number of hospitals or organisations performing radiation therapy, x-ray or radionuclide examinations are given. The number of patient treatments or examinations per year is also listed.

Radiotherapy/x-ray diagnostic hospital or organisation	Number of hospitals	Number of patient treatments/examinations per year
Radiotherapy treatments, public	9	10000
X-ray diagnostic examinations, public	120	3400 000
X-ray diagnostic examinations, private	20	
Radionuclide treatments/examinations	25	1100/51000

A questionnaire was in 2005 prepared for the customer of the NRPA SSDL in order to find the needs for dosimetry calibrations and protocols. About 20 organisations and departments got the mail with the questionnarie and the response was nearly 90 %.

In the field of measurement of radionuclides the laboratories performing measurements was also given a questionnaire, and a few was visited and interviewed. No laboratory holds standards for measurement of radionuclides.

The following results are given from the questionnaire:

Radiotherapy level, 9 respondents (radiotherapy centres).

All said it was highly important to have calibration in Norway for absorbed dose to water and air kerma for Co-60 beams. It was considered not that important for x-ray beams except among those who used them. The customers of NRPA SSDL also said it was highly important to have competence in calibration and dosimetry protocols at NRPA SSDL, and that they would benefit from it in the future.

Diagnostic level, 9 respondents.

The 9 respondents represented only a few of the 40 medical diagnostic users in Norway. New regulation for medical practitioners of x-ray requires measurement of dose to the patient. It is estimated that the results from the questionnaires showed only one fourth of the needs at diagnostic level.

The respondents needed calibration of 15 dosimeters and this was of high importance for them. They have had little benefit from the competence of the NRPA SSDL (calibration and dosimetry protocols) until now, but in the future they thought they would highly benefit from this competence.

Radiation protection level, 15 respondents.

All had portable detectors and one institution performed calibration in a setup with sources based on calibration from NRPA SSDL. Calibrations of their instruments were highly needed now, even though they do not have had that much advantage of the calibration at NRPA SSDL. In the future the calibrations at NRPA SSDL were highly needed.

Scientific research where dosimetry is of importance, 9 respondents.

All would benefit from calibration at NRPA SSDL. The dosimetry needs in their science in the future would continue, and they had the confidence that the NRPA SSDL could meet the requirements for their dosimetric competence.

The conclusions from the questionnaire were:

Radiotherapy: there is a market for the service which is served by NRPA and the clients are satisfied.

Diagnostic x-ray, research and radiation protection: a new market because of requirements in the regulations. NRPA has not served this segment and the clients express their interests and expectation in new expertise from NRPA in the future. Calibration campaigns in this field require more resources;

personnel, development of calibration routines and appropriate dosimetry standards. This capability may be payable. An increased total activity gives lower percentage administrative cost for the NRPA SSDL.

Radon

NRPA has carried out indoor radon measurements in connection with a program for mapping of indoor radon in Norwegian municipalities. There is reported indoor radon for 200 of 431 municipalities. 230 still need radon measurements. In the last 10 years indoor radon has been carried out in ~ 80 000 houses. Almost all kindergartens (3500) and schools have been measured. Passive integrating radon dosimeters have been used in the indoor radon measurements and both NRPA and private companies are performing the measurements. The service provides annually 8000 measurements, when there is no governmental mapping program or information campaign.

3.5 Sweden

The calibration needs for the dosimetric quantities in Sweden is split in two user groups with almost similar sizes, hospitals and industries. SSI itself also has a need for calibrated instruments. Official calibrations in Sweden for dosimetric quantities are only made at SSI as there is no accredited laboratory.

To indicate the need for calibrations the number of appliances and radionuclide laboratories used in health care and veterinary are given in table 8.

For radiotherapy the hospital have to calibrate at least one reference instrument every second year. The companies having individual dosimetry services shall calibrate dosimeters every third year. In both case they shall be calibrated at a national metrology institute under MRA or an accredited laboratory in a country, which have a multilateral agreement, MLA, with Sweden.

Table 8 Number of radiation appliances and radionuclide laboratories used in health care and veterinary X-ray practices at the end of 2004 in Sweden.

Appliances/laboratories	Number
X-ray diagnostic appliances (generators)	2000
Dental X-ray appliances	12000
Radiotherapy accelerators	60
Radiotherapy afterloading appliances	20
Veterinary X-ray appliances	300
Radionuclide laboratories	32

Established environmental objectives for Sweden can lead to an increasing demand for radon measurements in dwellings and at workplaces. This will also lead to an increased number of calibrations of instruments and detectors.

There is no National Reference Laboratory for activity measurements in Sweden. In practice, SSI has worked as a reference laboratory for radon measurements for many years. The possibility of giving the radon calibration laboratory at SSI the status of National Reference Laboratory is under discussion.

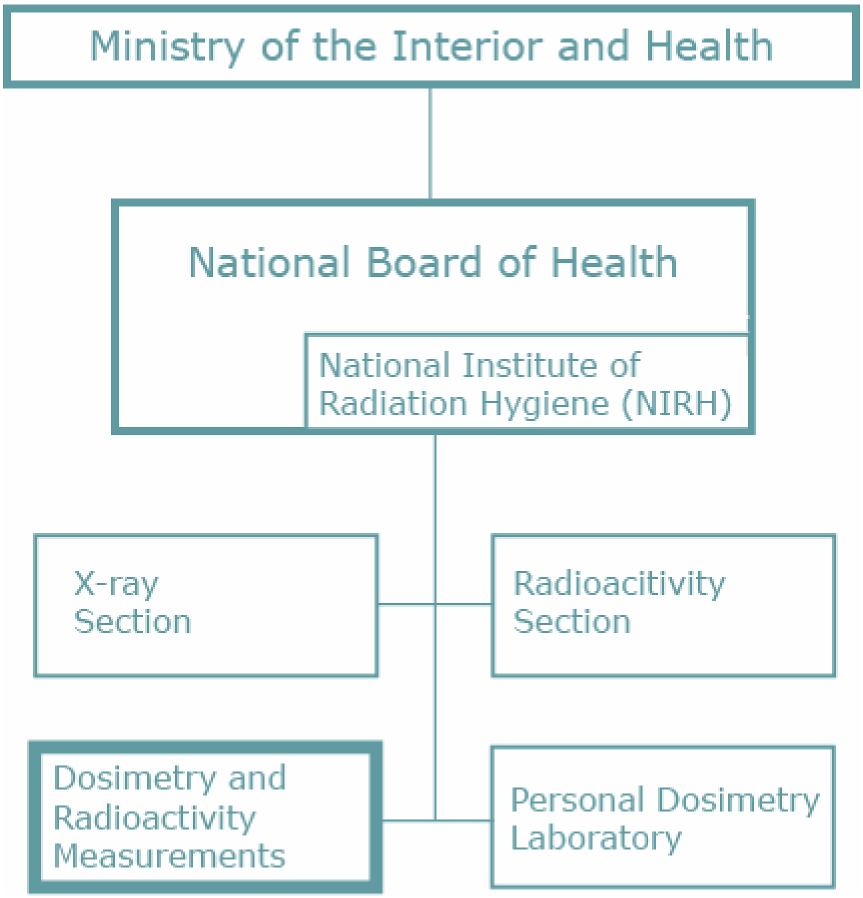
4 Status for the dosimetry in the Nordic SSDLs

4.1 The organisation of the dosimetry laboratories

Organograms from each country display how the radiation protection institutes make dosimetry visible.

The NIRH

Dosimetry is a part of the work carried out within the Section for "Dosimetry and Radioactivity Measurements" a small department in NIRH with 2 employees, one physicist and one technician. The SSDL is also included in this Section



The STUK

Radiation Metrology Laboratory is located at the department for Radiation Practises Regulation. In addition to the calibrations provided by the radiation metrology laboratory, the organisation is meant to assure the availability of the dosimetry expertise and to support the regulatory activities at the department of Radiation Practises Regulation.

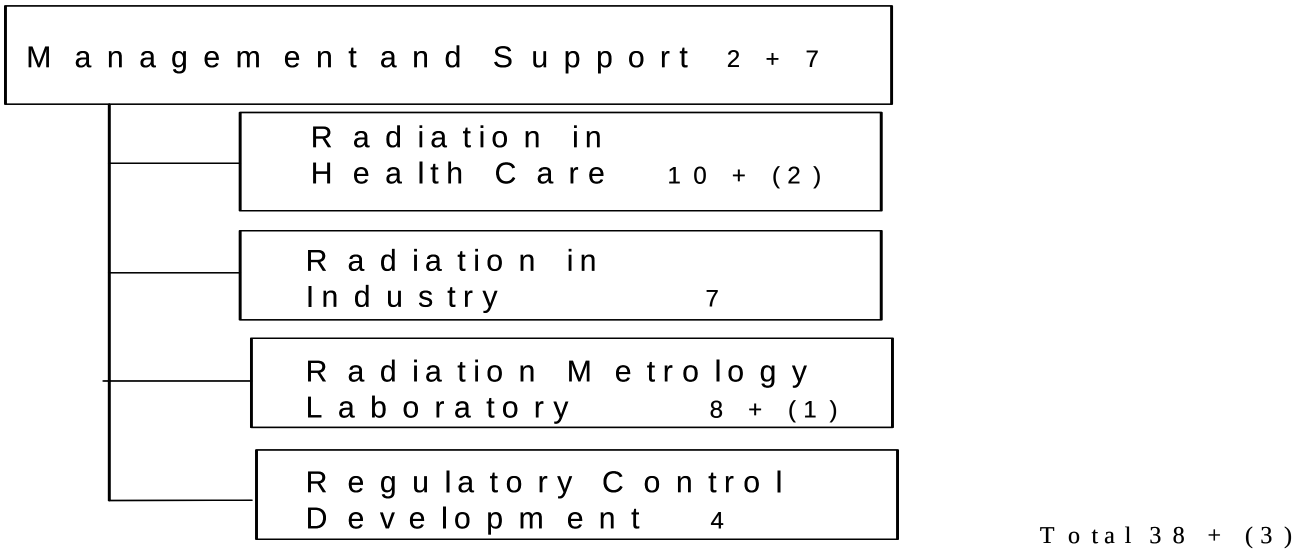


Figure 1 Organisation of department for radiation practises regulation of STUK.

The work of the staff of the radiation metrology at STUK is divided for the duties of other sectors and 3 – 4 man-years are allocated to the radiation metrology activities (maintenance of standards, services, development/research for metrology). In addition to the metrology, the other duties at the Radiation Metrology Laboratory cover e.g. the research for x-ray image quality evaluation and services for testing of x-ray equipments.

At the department, the research for medical use of radiation, radiation metrology and to some extend also the research on individual dose monitoring are organised as projects according to the Figure below. The development and research for applied dosimetry is performed together with the experts of the other sections.

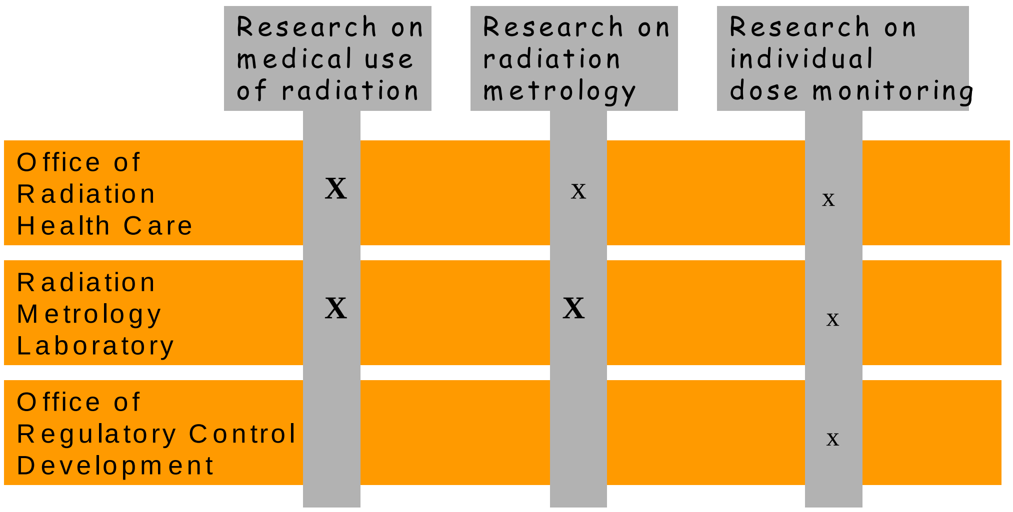
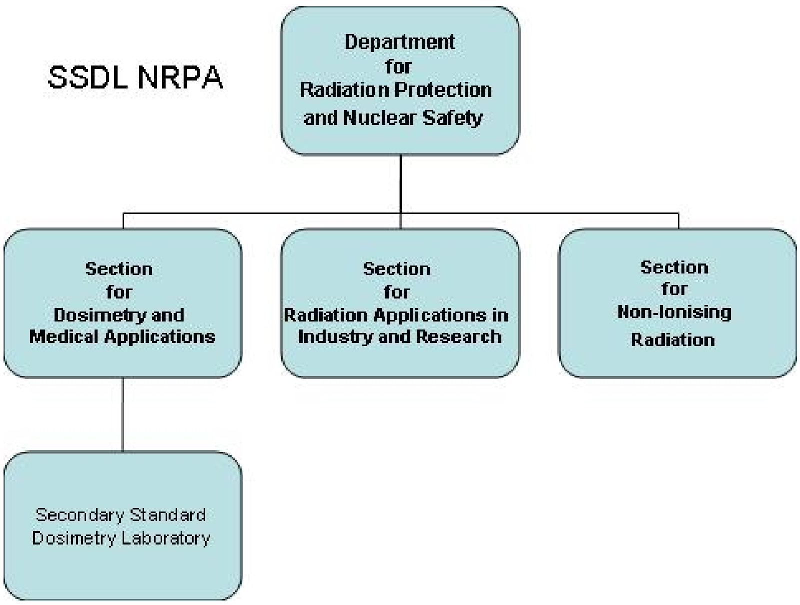


Figure 2 Project organisation for research at the radiation practises regulation at STUK.

At STUK the radiation metrology is also recognised as a process. This process includes metrology for ionising radiation (dose quantities and activity) and non-ionising radiation. The maintained quantities as a national laboratory are those included in MRA i.e. the dose quantities (see Tables in appendix 5.).

The staffs of the section radiation in health care perform site visits to the hospitals. An essential part of this work is the comparative measurements performed by the staff of the radiation in health care. STUK has also a mechanical workshop what can be used effectively in the development of laboratory facilities.

The NRPA



The Secondary Standard Dosimetry Laboratory at NRPA is located at the department for Radiation Protection and Nuclear Safety. The SSDL NRPA aims at making dosimetry expertise available to serve medical and other users of radiation and to support the regulatory activities. A total of 4 persons is working in the SSDL group, dealing with metrology work and authority related work. The operating budget is 200 000 NOK. Large investments are not included. The services are free of charge for governmental users as hospitals.

Figure 3 Organisation of the NRPA SSDL in the Department for Radiation Protection and Nuclear Safety

The dosimetry laboratory at NRPA (NRPA SSDL) was in 2004 designated as responsible for the units, becquerel (Bq), gray (Gy) and sievert (Sv), in Norway. NRPA SSDL serves as a National Metrological Institute (NMI) in the field of ionising radiation and holds standards for the calibration of it. The dosimetry laboratory has a self declared quality system following EN-ES ISO/IEC 17025:1999.

The CMCs are presented for the EUROMET, but not published on the BIPM web.

The SSI

The metrology laboratory (National laboratory for ionising radiation) is a part of the Department of Occupational and Medical Exposures, see figure. A total of 4.8 persons are working in the SSDL group, dealing with metrology work and authority related work. On average for five years, 2.5 man years (1.5 physicists and 1 engineer) are spent per year on the metrology activities. The cost for the metrology work is about 3 500 000 SEK (including all cost for investigations in equipment and building and rent, although the laboratories is also used for other purposes). SSI charges the customers for calibration. The work not included in metrology work is mainly related to radiation protection research and investigations.

Figure 4 The Swedish National Laboratory for Ionising Radiation in the Department for Occupational & Medical Exposures

Table 9 Summary of Nordic physicists, engineers and man-years for radiation metrology. Man-years are given in parentheses.

Number and (Man-years)	Physicists	Engineers and technicians	Total for metrology	Comments
NIRH	1 (0.5)		1 (0.5)	-
STUK	5 (2.5)	3 (1)	8 (3.5)	Numbers of staff are for radiation metrology laboratory. Only 2 physicist and 2 technicians are working mainly for radiation metrology.
GR	1 (0.2)	-	1 (0.2)	1 physicist is testing diagnostic dose meters in x-ray beams
NRPA	4 (1.8)	0	4 (1.8)	2 physicist are mainly working in dosimetry and two others physicist are part time workers
SSI	4 (1.7)	1 (0.8)	5 (2.5)	-
Nordic total	15	4	19	

4.2 Calibration and measurement capabilities

The calibration and measurement capabilities for services are presented in Appendix 5. These services are provided both for internal and external use in the institutes.

4.3 Calibration certificates

In table 10 the average number per year of certificates for radiotherapy, diagnostic and radiation protection calibrations at the Nordic SSDLs are reported. The figures represent an average number in the years 2000-2005. In radiation protection also irradiation of passive dosimeters are included.

Table 10 The average number of calibration certificates per year during the last five years.

Type	Radiation therapy	Diagnostic x-ray	Radiation protection	Radioactivity	Total
NIRH*	8	10	15	3	36
STUK	19	24	79		122
GR	0	0	0		0
NRPA	62**	2	2		66
SSI***	25	24	64		113

*The average number of calibration documents written in Denmark in 2003 to 2005.
**Numbers from 2005 for NRPA. Double production because of close down in 2006.
*** The laboratories were closed between November 2003 and May 2004. Year 2004 is therefore excluded.

In figure 5 the variations in the number of calibrations in Sweden during a period of 11 years are shown. Due to the relatively small number of calibration the yearly variation could be rather large and an increase or reduction of up to 50% from one year to another is not unique.

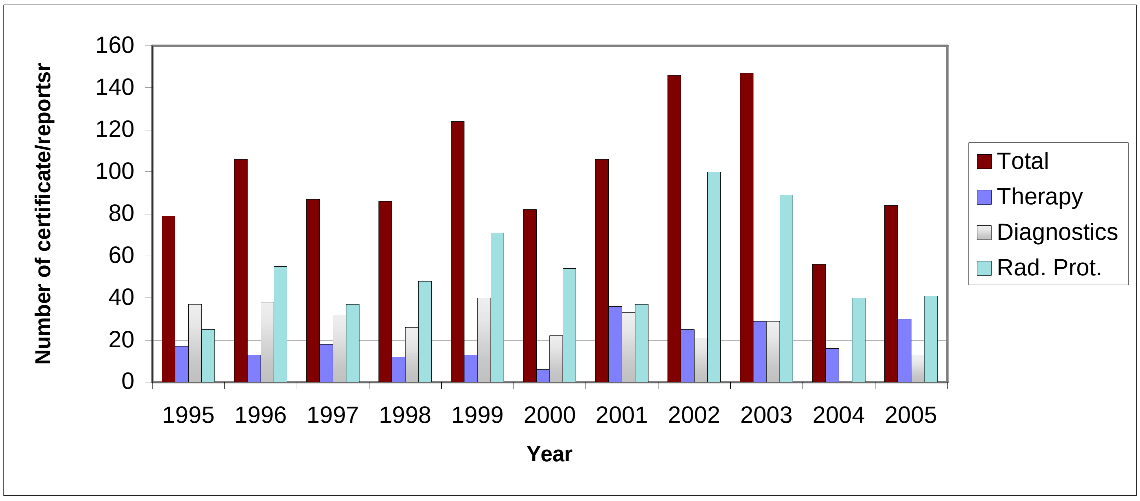


Figure 5 Yearly variations in the number of calibrations in Sweden.

4.4 Quality systems, accommodation and environmental conditions

In table 11 the main installed radiation equipment for calibration and for other purposes in each country are shown.

Table 11 Major radiations source installations in the Nordic Dosimetry Laboratories

Application	NIRH	STUK	GR	NRPA	SSI
High-energy external beam therapy	Cobalt unit	Cobalt unit	-	Cobalt unit	Cobalt unit
X ray generator **Tubes**	2 units 320 kV generator 50kV generator	2 units 2 tubes (320 kV and 160 kV)	-	1 unit 2 tubes (320 kV and 160 kV)	2 units 2 tubes (350 kv and 10 kV) 1
X-ray diagnostic **50- 150 kV**	3 units	Ceiling mount tube, under coach tube A mammo-graphy unit. These units are used mainly for image quality evaluations.	1 unit 1 tube (150 kV)	Ceiling mount tube, under coach tube. A mammo-graphy unit. Not for calibration	
Sealed radioactive gamma sources	Cs-137, Am-241	Co-60, Cs-137, Am-241	Cs-137	Co-60, Cs-137, Am-241	Co-60, Cs-137, Am-241
Sealed radioactive beta sources	Kr-85	Sr-90+Y-90, Tl-204, Kr-85.		Sr-90+Y-90, Tl-204	Sr-90+Y-90, Tl-204
Neutron sources	Cf-252	Am-Be		Am-Be	
Brachytherapy source	No		No	No	No
Radioactivity standards	NPL-CRC Secondary Standard Cs-137 reference	Radon room.	No	Plans for radon room	No

NIRH

The X-ray generators and Sealed radioactive sources are placed and used in 5 shielded rooms in the basement of the building in Herlev where NIRH is located.

The QS is still under development.

STUK

The laboratory rooms STUK of three irradiation rooms for x-rays, radiation protection and for radiotherapy. STUK has operated in these premises since 1994.

The QS of the Radiation Metrology Laboratory (RML) of STUK is constructed and described according to the requirements of ISO 17025. As the other National Metrology Laboratories in Finland, the approval of the QS of RML of STUK is based on the Self Declaration approach. The QS is approved by the EUROMET QS-forum in 2003.

NRPA

The SSDL of NRPA has one irradiation room for x-rays, radiation protection and for radiation therapy. NRPA has operated in these premises since 1975.

The QS of the SSDL NRPA is constructed and described according to the requirements of ISO 17025:1999. As the Justervesenet in Norway, the approval of the QS of the dosimetrylab is based on the Self Declaration approach. The QS is approved by the EUROMET QS-forum in 2005.

SSI

The SSDL have three laboratories, one with a ^{60}Co source for therapy calibration, one with an irradiator for radiation protection calibration and irradiation and one laboratory with two x-ray equipments for therapy, diagnostic x-ray and radiation protection calibrations. In connection with the move to a new building investigation in new equipments were done, one irradiator with sources, three positioning rail and one strong ^{60}Co source were bought. New x-ray equipment will be bought in 2006. The Swedish SSDL then has laboratories and equipment well in line with the need for a secondary standards laboratory. The only big investigation foreseen during the next five years is eventually beta calibration equipment.

The laboratory has a quality system, which from 1980 was based on the standard EN 45001 and from 2003 is based on the standard ISO 17025. Swedish Board for Accreditation and Conformity Assessment, SWEDAC, inspects the quality system every second year. The quality system was presented and accepted on a EUROMET QS-forum 2002. The CMCs are included in the BIPM database from 2005.

4.5 Research and development

The research and development at radiation metrology laboratory is aimed at internationally comparable reliability of national standards for dosimetry, for optimal calibration techniques for dosimeters and for reliable methods for applied dosimetry. See table 12 for an overview.

NIRH

NIRH participate in the developments of new measurement methods in radionuclide metrology for medical application as a member of International Committee of Radionuclide Metrology (ICRM). This includes participation in comparisons and in Monte Carlo calculations of the sensitivity of Dose calibrators.

STUK

A calibration service for dose-area product meters (DAP meters) used in diagnostic radiology was established in 2004. As a part of the developing process an inter-laboratory comparison for calibration of DAP meters in the Nordic countries. Results of the comparison indicate reasonable consistency between Nordic laboratories although development for specifying the radiation quality is required.

The method for determination of the absorbed dose to soft tissue for beta-rays using an extrapolation ionization chamber was updated in 2004 according to the recent ISO standards. The laboratory participated also in the EUROMET 739 comparison for 90Sr beta radiation. A study for calibrating scintillation dosimeters for beta ray radiotherapy was performed.

The research at Department of Radiation Practices Regulation is organised as projects, including also the projects for applied dosimetry and metrology, see Figure 2. In 2002 – 2004 the Radiation Metrology Laboratory has participated in a EU shared cost project, DIMOND 3 – *Measures for optimising radiological information and dose in digital imaging and interventional radiology*. STUK contribution included activities both for dosimetry and image quality evaluation. The project was finished in March 2004.

In 2005 – 2007 the laboratory is participating in EU coordinated action SENTINEL- *Safety and efficacy for new techniques and imaging using new equipment to support European legislation (6th framework programme)*. STUK contribution includes activities for dosimetry surveys and image quality evaluation

In 2005 – 2007 the laboratory is participating in IAEA Coordinated Research Project "*Testing of the Implementation of the Code of Practice on Dosimetry in X-ray Diagnostic Radiology*". STUK activities cover dosimetry testing both at the calibration laboratory and at clinics for applied dosimetry.

An international audit for research at STUK was performed during 2005.

In addition to the routine calibration and measurement capabilities described in the Appendix 1, laboratories have other skills and capabilities related to the dosimetric and metrological work. These capabilities are described in Table 12.

NRPA

At NRPA the aim of research and developments are the needs for traceable dosimetry in the use of ionising radiation. The activity has mainly met the needs for the health care users performing radiation therapy. The needs for reliable measurements according to international recommendations are increasing both in x-ray diagnostic area and radiation protection. The requirements for quality assurance of the use for ionising radiation call for regularly traceable calibrations.

The priority for developments is twofold: to finalise the calibration setup for DAP meters, and to investigate the alanine dosimetry for radiotherapy in a pilot study.

SSI

A calibration method for DAP meters was established in the beginning of 2005 and another method to calibrate well chambers used for high dose rate ^{192}Ir sources was established 2006.

A detailed investigation of the dose rate in the ^{60}Co therapy beam will be done to compare the dose rate determined with ion chamber with the dose rate determined with a water calorimeter. Included in the determination is also simulation of the fluence with Monte-Carlo calculation.

There is a need for calibration of radiation protection instruments for lower x-ray qualities 10 – 30 kV, and it is therefore proposed to set up these qualities.

Research within the Swedish SSDL group (but not included in the metrology work) have for many years been directed towards radiation quality investigations as the dose is not enough to describe the effect of radiation. There are three main projects that have been going on the last years. Two of them are EU-projects, one to determine doses on board aircraft and one to investigate personnel dose meter used in mixed neutron gamma fields. The third project is related to measurement of beam quality in therapeutic neutron and photon beams. In all these projects it is necessary to have laboratories with calibrated sources.

SSI also frequently finances research projects within the area of dosimetry and metrology. The research projects shall support the work of SSI. The SSDL personnel take actively part in these projects.

The Swedish SSDL group have a strategy plan to build up competence in Monte-Carlo calculation first of all as a tool in radiation protection dosimetry but also as a help in the metrology work.

Table 12 ***Dosimetry and other capabilities.*** *In addition to the routine services described in the Tables in the Appendix 5.*

Area	Description	Instruments	Quantities and traceability	Laboratories	Comments
Photon and electron dosimetry					
x-ray therapy and Brachytherapy	Research projects	Liquid ion chamber	SSI Co-60 SSI xray	SSI,	
High energy photon- and electron therapy	Development of alanine dosimetry for quality assurance	EPR-reader and alanine pellets	Absorbed dose to water / NRPA Co-60	NRPA	In cooperation with university and hospital
Charged particles and beta dosimetry					
Microdosimetry			LET, y	SSI, STUK	At STUK for high dose rates /BNCT applications
Proton therapy	Research projects	Calorimetry	SSI Co-60	SSI	
Eye applicators for radiotherapy	Research	Extrapolation IC	Absorbed dose to tissue	STUK	
Neutron and mixed photon/neutron dosimetry					
Cosmic radiation	Mixed field dosimetry	Sievertinstr.	D, LET, Q, H* SSI Cs-137 PTB neutron	SSI	
Power plants	Mixed field dosimetry	Sievertinstr Berthold	D, LET, Q, H* SSI Cs-137 PTB neutron	SSI	
Boron neutron captute therapy	Mixed field dosimetry	Paired ionisation chambers	D, high dose rates.STUK, Co-60	STUK	
Other					
Electrometers	Measurements of low currents (fA-pA)			All	SSI has an expert for electrometers/ measurements.
Monte Carlo	Radioactivity applicat.	Penelope, EGS	Dosecalibrator	NIRH	
Monte Carlo	Dosimetry applications	MCNP, EGS		SSI	
Monte Carlo	Dosimetry applications	MCNP, (EGS)		STUK	
Monte Carlo	Patient dosimetry for diagnostics	PCXMC	D, Organ doses, effective dose	STUK	PCXMC code is developed at STUK.
Spectrometry	X-rays	High purity Ge-detector		STUK, NRPA, SSI, GR	
Image quality evaluation	Diagnostic dose/image quality optimisation	Research work		STUK	Software Fluo–o – image
Tests of X-ray equipments	Compliance tests for safety of diagnostic X-ray units are performed.	Service		STUK	Manufacturers of diag. mammography and dental X-ray units

5 Radon activity

NIRH

The Institute does not have facilities for radon measurements and at the moment no investigation of the radon exposure of the Danish population is carried out.

STUK

The Natural Radiation Laboratory (NRL) of STUK performs research on occurrence, mitigation and prevention of indoor radon in dwellings and workplaces. STUK has studied risks of radon in indoor air by performing two epidemiological studies and by participating in international epi-studies. The NRL studies also the occurrence and treatment methods of natural radioactivity in household water as well as terrestrial gamma radiation. The NRL provides measurement services for measurements of indoor radon and radioactivity in drinking water and natural radioactivity in soil samples.

NRL of STUK has a radon calibration room and secondary standard level instruments (ionisation chambers) for realisation of radon concentration. The reference instrument has traceability to PTB. Key measurement technologies of radon in indoor air are passive integrating alpha track dosimeter and continuous radon monitors based on either ionization chamber or scintillation cells. The measurement technologies of radioactivity in drinking water are liquid scintillation counting and alpha spectrometry.

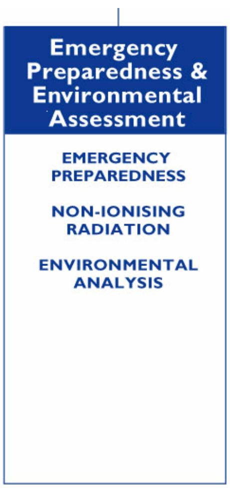
The total annual number of indoor radon measurement in 2001-2005 has been 5000-12000 including research, services and quality control. The indoor radon measurements are accredited (ISO 17025) services at STUK

NRPA

The Norwegian Radiation Protection Authority (NRPA) has a radon calibration room which is being used for batch calibration of etched track detectors (CR-39) and other instruments. Calibration of secondary standard level instruments (two ATMOS instruments), which are used to convert exposure of radon detectors (etched track detectors) to integrated radon concentration, are being calibrated on routine basis at SSI. NRPA take part in the annual intercomparison of etched track detectors organised by HPA/RPD in UK. In 2005 a considerable number of etched track detectors (CR-39) were exposed at different radon levels at PTB in Germany. Some of these detectors were exposed at very high levels of radon in order calibrate for occupational monitoring in underground workplaces and for measurements of radon in soil. The measurements of radon in water are carried by liquid scintillation counting.

In Norway, radon measurements are offered on commercial basis by several private companies. Most of these companies are representing accredited laboratories abroad fulfilling the basic requirements to offer their services in Norway.

SSI



The radon laboratory is a part of the section for Environmental Analysis in the Department of Emergency Preparedness and Environmental Assessment. The work related to calibration activities amounts to approximately one man year (0.5 physicist and 0.5 technician).Calibration of instruments and detectors used for indoor radon measurements has been carried out at the Swedish Radiation Protection Authority (SSI) since the late seventies. Measurement protocols for radon measurements in dwellings and at workplaces require regular calibration of the measurement devices. Instruments for continuous measurements have to be calibrated at least every 12 months. Passive detectors such as track-etch detectors are calibrated by exposure of a selection of the total production of detectors at each laboratory offering measurements.

The calibrations are based on standards traceable to the National Institute of Standards and Technology (NIST) through the use of a ^{226}Ra standard reference solution. The reference activity is used to calibrate secondary standard instruments in order to establish the traceability for the calibration of field instruments and detectors in the radon-room at SSI.

The number of instruments and detectors exposed in the radon room are shown in the diagram below.

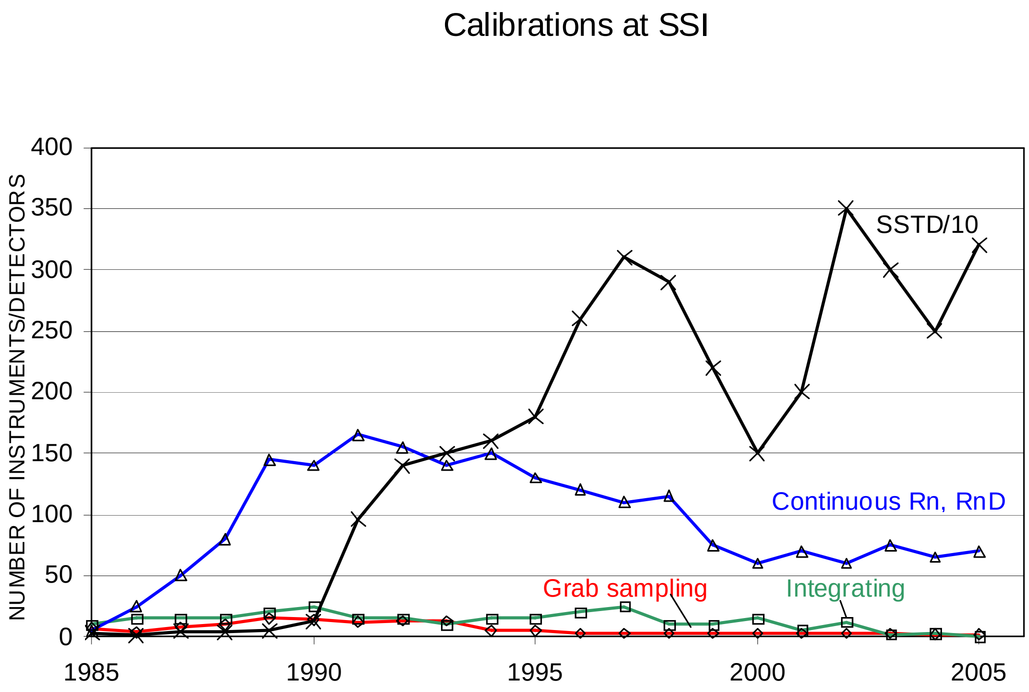


Figure 6 Number of instruments and detectors exposed per year in the radon room at SSI.

Commercial laboratories performing measurements of radon in water shall have their calibration verified by intercomparison measurements with SSI.

Since 1991 it has been possible for Swedish companies and laboratories to be accredited for measurement of ^{222}Rn in indoor air and in water. This accreditation is issued by SWEDAC. It is based on the international standard EN ISO/IEC 17025 and requirements in the measurement protocols. Today there are four laboratories accredited for measuring radon in indoor air and four for radon in water.

Table 13 ***Radon measurements identifying instruments and traceability***

	Country	**Quantity**	**Reference instrument**	**Traceability**	**Status**
Rn-222 Radon in air	Den				
	Fin	Bq m^{-3}	AlphaGuard	PTB	In use
	Ice		non		
	Nor	Bq m^{-3}	Atmos and etched track	SSI (NIST) PTB	
	Swe	Bq m^{-3}	**Ra-226 standard reference solution**	NIST	
Rn-222 Radon in water	Swe	Bq m^{-3}	**Ra-226 standard reference solution**	NIST	

6 Nordic cooperation

6.1 The Nordic dosimetry meetings.

The Nordic cooperation in dosimetry has been a close and fruitful activity since the 1920ies. Nordic dosimetry meeting were arranged in the 1970ies and 1980ies. The cooperation was taken up again in 2000 and yearly meetings have been arranged since.

The Nordic radiation protection authorities approved a mandate for the cooperation in 2002, which was revised in 2003. The scope of the Nordic working group in dosimetry is:

1. Accuracy and consistency of dosimetry
    a. Calibrations at national standard dosimetry laboratories
    b. Applications for radiation protection and medical dosimetry (issues are mainly related to radiotherapy)
2. Verification of quality assurance of radiotherapy

The main topics are implementation of the absorbed dose to water both at the SSDLs and in the clinics. Another calibration task is the x-ray diagnostic DAP meter. A comparison of DAP meters has been arranged and information about implementation in the clinics are exchanged. The work done by Nordic experts for IAEA has been reviewed in the group meetings. Status reports from each dosimetry laboratory has been given and information exchanged. News from the Nordic Association of Clinical Physics (NACP) and the International Committee on Ionising Radiation (CCRI) is on the agenda.

6.2 Dose area product meter

The dose area-product (DAP) meters are widely used in the diagnostic x-ray equipments for control of the patient dose. The Nordic laboratories have a useful co-operation in this field and two co-operative actions have been launched 1) intercomparison of DAP meter calibrations and 2) preparation of a possible common Nordic guidance for users on calibrations of DAP meters on-site at the hospitals. The Intercomparison was performed in 2004 and a report is under preparation. At STUK guidance for users is prepared (in Finnsih) and it is aimed to translate this document for possible wider use and modifications in the Nordic countries. IAEA is working on a Code of Practice for diagnostic dosimetry which covers this area therefore it must be reviewed whether Nordic recommendations are still needed.

6.3 Workshop 2006

The 1st Nordic workshop on dosimetry will take place in summer 2006 at SSI. The aim of the workshop is to open a forum for new and experienced personnel to meet for lectures and practical laboratory work. It is supposed that all participants are active in the workshop and that the training will give more skilled personnel for the Nordic dosimetry work.

Topics for the workshop are uncertainty budget, electrometer calibration, measuring of x-ray spectrum, water calorimeter, dosimetry in small fields etc.

7 List of acronyms and links

Acronym	Stands for. Hyperlink.
BIPM	Bureau International de Poids et Mesures. The task of the BIPM is to ensure world-wide uniformity of measurements and their traceability to the International System of Units (SI). www.bipm.fr/en/home/ (May 2006)
CCRI	Consultative Committee for Ionizing Radiation. Created 1958. Secretariat at BIPM. www.bipm.fr/en/committees/cc/ccri/ (May 2006)
CIPM	International Committee for Weights and Measures. Secretariat at BIPM. www.bipm.fr/en/committees/cipm/ (May 2006)
CMC	Calibration and Measurement Capabilities. Quantities for which calibration and measurements certificates are recognized by institutes participating in part two of the arrangement (MRA). All CMCs are accessible in a data base at BIPM. www.bipm.fr/en/cipm-mra/ (May 2006)
DAP	Dose area product. Transmission ionisation chamber used in the beam of conventional diagnostic x-ray equipment as an indicator of patient dose.
DIMOND	Measures for optimising radiological information and dose in digital imaging and interventional radiology.
EGS	Electron Gamma Shower (A data package for the Monte Carlo simulation of the coupled transport of electrons and photons) http://www.slac.stanford.edu/egs/ (June 2006)
EUROMET	European Collaboration in Measurement Standards. EUROMET is a cooperative voluntary organisation between national metrology institutes (NMIs) in the EU and EFTA, including the European Commission. Established NMIs from other European states can also be members subject to the agreement of existing members. Currently, EUROMET has 34 members, with nearly every European state represented. www.euromet.org/ (May 2006)
GR	Geislavarnir Rikisins (Icelandic Radiation Protection Institute), Iceland www.gr.is (May 2006)
HDRL	High Dose Reference Laboratory
IAEA	International Atomic Energy Agency (Dosimetry and Medical Radiation Physics) www-naweb.iaea.org/nahu/dmrp/ (May 2006)
ICRM	International Committee of Radionuclide Metrology
ICRU	International Commission on Radiation Units and Measurements www.icru.org (May 2006)
IEC	International Electrotechnical Commission www.iec.ch (May 2006)
iMERA	Implementing Metrology in the Research Area. EUROMET project.
IRMM	EU, Institute for Reference Materials and Measurements in Geel, Belgium www.irmm.jrc.be (May 2006)

Acronym	**Stands for. Hyperlink. Continued**
ISO	International Standardisation Organisation www.iso.org (May 2006)
JV	Justervesenet (Norwegian Metrology Service) www.justervenest.no (May 2006)
MCNP	Monte Carlo N-Particle code that can be used for neutron, photon, electron, or coupled neutron/photon/electron transport. http://mcnp-green.lanl.gov/index.html (June 2006)
MIKES	Centre for metrology and accreditation, Finland www.mikes.fi/ (May 2006)
MRA	Mutual Recognition Arrangement organised at BIPM www.bipm.fr/en/cipm-mra/ (May 2006)
NIRH	National Institute of Radiation Hygiene, Denmark www.sst.dk/Forebyggelse/Straalehygiejne.aspx? (May 2006)
NMI	National metrology institutes
NRL	Natural Radiation Laboratory, Finland
NRPA	Norwegian Radiation Protection Authority (Statens strålevern), Norway www.nrpa.no (May 2006)
PCXMC	A PC-based Monte Carlo program for calculating patient doses in medical x-ray examinations. Developed at STUK. http://www.stuk.fi/sateilyn_kayttajille/ohjelmat/PCXMC/en_GB/pcxmc/ (June 2006)
PSDL	Primary Standard Dosimetry Laboratory
RI	Ionizing radiation. This metrology area covers the fields of dosimetry, radioactivity and neutron measurements.
SENTINEL	Safety and efficacy for new techniques and imaging using new equipment to support European legislation (6th framework programme)
SSDL	Secondary Standard Dosimetry Laboratory www-naweb.iaea.org/nahu/dmrp/ssdl.asp (May 2006)
SSI	Statens strålskyddsinstitut, (Sdedish Radiation Protection Authority), Sweden www.ssi.se (May 2006)
STUK	Säteilyturvakeskus (Radiation and Nuclear Safety Authority), Finland www.stuk.fi (May 2006)
SWEDAC	Swedish Board for Accreditation and Conformity Assessment, Sweden www.swedac.se (May 2006)
TC-IR	Technical Committee on Ionising Radiation, EUROMET www.euromet.org/tc/ionrad.html (May 2006)
TRS xxx	Technical Report Series. Publication from the IAEA.
WHO	World Health Organization www.who.int/en/ (May 2006)

1 Appendix A short history of Nordic radiation metrology

The SSDLs of the Nordic countries were established in the 1970ies. The historical background in Nordic dosimetry goes back to 1926 when Rolf Sievert published his work on the *Kondensatormessunginstrument* later called the ionisation chamber [1, 2]. The unit for effective dose, sievert (Sv), was later named after him. In the 1920ies the need for dosimetry in medical applications of radiation was pronounced, and physicists started the work on clinical dosimetry and dosimetry standardisation. Primary standards for the realisation of the exposure (Röntgen) were set up in Sweden, Finland, Norway and Denmark. New versions and development of these standards improved the dosimetry, and the last primary standards were taken out of use in the 1980ies. The primary standards were at that time replaced by ionisation chamber calibrated at Bureau International de Poids et Mesures (BIPM), National Physical Laboratory (NPL) or Physikalisch-Technische Bundesanstalt (PTB). Visits to the Iceland by physicists from the other institutes completed the Nordic dosimetry work.

The Nordic radiation protection institutes were founded on the base of the dosimetry work, and the physicists from them served hospitals countrywide measuring the amount of radiationfrom x-ray tubes and radium tubes. The amount of radiation to the exposed personnel was also measured.

References

1. Sievert, R. M. Eine einfache, zuverlässige Vorrichtung zum Messen von Tiefendosen. Acta Radiologica 5 s 468 Stockholm 1926.
2. Sievert, R. M. Eine Methode zur Messung von Röntgen-, Radium und Ultrastralung nebst einige Untersuchen über de Anwendbarkeit derselben in der Physik und der Medizin. Acta Radiologica Supplementum XIV. Stockholm 1932.

2 Appendix The Metre Convention, CIPM and CCRI.

The Metre Convention (Convention du Mètre) is a diplomatic treaty which gives authority to the General Conference on Weights and Measures (Conférence Générale des Poids et Mesures, CGPM), the International Committee for Weights and Measures (Comité International des Poids et Mesures, CIPM) and the International Bureau of Weights and Measures (Bureau International des Poids et Mesures, BIPM) to act in matters of world metrology, particularly concerning the demand for measurement standards of ever increasing accuracy, range and diversity, and the need to demonstrate equivalence between national measurement standards.

The Consultative Committee for Standards of Ionizing Radiations (Comité consultatif pour les étalons de mesure des rayonnements ionisants, CCEMRI) was set up in 1958. Its name was changed to Consultative Committee for Ionizing Radiation (CCRI) by the CIPM in 1997. Present activities concern matters related to the definitions of quantities and units, standards for x-ray, γ-ray, charged particle and neutron dosimetry, radioactivity measurement and the international reference system for radionuclides (SIR), and advice to the CIPM on matters related to ionizing radiation standards.

3 Appendix MRA and EUROMET.

At a meeting held in Paris on 14 October 1999, the directors of the national metrology institutes (NMIs) of thirty-eight Member States of the Metre Convention and representatives of two international organizations signed a Mutual Recognition Arrangement (MRA) for national measurement standards and for calibration and measurement certificates issued by NMIs. The MRA has now been signed by the representatives from 45 countries and 2 international organizations, one of them being IAEA.

The MRA is a response to a growing need for an open, transparent and comprehensive scheme to give users reliable quantitative information on the comparability of national metrology services and to provide the technical basis for wider agreements negotiated for international trade, commerce and regulatory affairs.

In Europe the responsible organization for implementing the MRA is the European Collaboration in Measurement Standards (EUROMET). EUROMET is a cooperative voluntary organisation between national metrology institutes (NMIs) in the EU and EFTA, including the European Commission. Established NMIs from other European states can also be members subject to the agreement of existing members. The objective of EUROMET is to promote the coordination of metrological activities and services with the purpose of achieving higher efficiency. National Metrology Institutes clearly are different from the majority of laboratories which offer calibration services. The most obvious distinction is that NMIs are themselves holders of the national standards to which the calibration services of accredited laboratories are traceable. In the Nordic countries the dosimetry laboratory of Denmark, Finland, Norway and Sweden are NMIs. They each have a designated Contac Person (CP), meeting annually in the EUROMET Ionising Radiation Technical Committee (TC-IR) CP-meeting.
(*According to MIKES, Finland there is only one NMI in each country, the signatory of MRA. Laboratories having national standards are called national metrological laboratories, NMLs. This means that all the Nordic SSDLs are NMLs*)

EUROMET recommends that NMIs' routine calibration services for external customers should comply with the requirements of the MRA. Current best practice points to the ISO/IEC 17025 standard. Operations in accordance with ISO/IEC 17025 criteria must include the demonstration of traceability to the SI units through a national standard. In particular, where traceability is taken from another NMI, this must be demonstrated through a calibration certificate produced within the QS of the other NMI. For qualified quality system EUROMET makes no distinction between third party accreditation and self-declaration. Its policy is, however, that QS of EUROMET members should be consistent with the requirements of the CIPM's MRA.

According to the MRA the degree of equivalence of calibration and measurement capabilities between individual NMIs is verified by the approved Quality System (QS) and the results of key comparisons. According to MRA and the rules of EUROMET the QS of an NMI shall fulfil the requirements of the ISO Quality Standard 17025. The recognition and approval of the QS of an NMI can be based either on the Third Party Accreditation or on Self-Declaration approach. In both cases the QS of the NMI has to be consistent with the requirements of ISO 17025 and shall be recognized and accepted by the Technical Quality Committee (TC-Q) of EUROMET. The TC-Q is the EUROMET operational instrument to share and develop knowledge on ISO/IEC 17025 and on its implementation in the National Metrology Institutes (NMIs). It has no formal auditing or judgement authority, but by asking how an NMI's QS is implemented, and by offering feedback on best practice, this Forum has become the EUROMET way of doing QS review by peers.

Outline of the calibration and measurement capabilities in the field of ionising radiation and radioactivity. Here we will give some general information on standards, units, laboratory work, comparisons of standards and dosimetry protocols.

This is the part of the BIPM database concerning Appendix C of the MRA. It includes the Calibration and Measurement Capabilities (CMCs) declared by National Metrology Institutes.

The co-operation in the field of metrology of ionizing radiation is different from length mass etc. in the way that we have a historical link to the radiation protection institutes.

4 Appendix Dosimetry: The IAEA/WHO SSDL Network

In 1976, the International Atomic Energy Agency (IAEA) together with the World Health Organization (WHO) established a network of Secondary Standard Dosimetry Laboratories (SSDLs), known as the IAEA/WHO SSDL Network.

Denmark, Finland, Norway and Sweden joined the SSDL network in the 70-ties. The SSDLs function is to fulfil a nationwide metrological function based on traceability to approved measurement standards. This includes the provision of certified calibrations for instruments used in radiation therapy and other fields.

The requirements for the status as an SSDL in the IAEA/WHO SSDL Network are:

1. The competent national authorities may nominate a single SSDL, or an SSDL organization, for participation in the SSDL Network.
2. National recognition and support of an SSDL are prerequisite for participation in the SSDL Network.
3. Maintenance of radiation dosimetry standards at the SSDL:
    a. The laboratory's standards shall be calibrated by a PSDL or at the IAEA, at intervals not exceed 5 years.
    b. Radiation sources, calibration facilities, and associated equipment shall be properly documented and maintained in full working order.
4. A comprehensive quality assurance (QA) programme should be developed which follows the Agency recommendations:
    a. Internal QA (ISO/IEC 17025) including redundancy checks on the standards and peripheral equipment, up-date staff training, improvement to equipment or techniques as appropriate, documentation and record keeping.
    b. External QA including measurement assurance tests through the IAEA/WHO TLD or ion chamber irradiation programmes and intercomparison of standards and techniques with other SSDLs.
5. The SSDL should participate with PSDL or Agency in the resolution of any dosimetry discrepancies identified by adopting the appropriate action levels established by the SSDL Network Secretariat.
6. The SSDL should cooperate with the SSDL Network Secretariat in the exchange of information and improvements to their instruments measurements and techniques
7. Annual reports should be made to the SSDL Network Secretariat on the status of the standards and radiation sources, on type and number of calibrations performed for users, the present number of staff, the training received and training provided, and on the implementation of the quality assurance programme.
8. Collaboration with end-users and services provided:
    a. The major role of the SSDL is the dissemination of radiation dosimetry standards to users through instrument calibration, which include dissemination of calibration procedures, and practical help to end-users on instrument use in their particular application.

b. Calibration certificates for users' equipment should be developed which provide not only the numerical value of the calibration coefficient but also all other information necessary to understand how to use the coefficient. This includes the coordinations of calibration, the instrumentation used, any special conditions and a full uncertainty statement.

9. Some SSDLs, with the appropriate facilities and expertises, may also conduct quality audits of the end use of calibrated dosimeters, for example by:
    a. Providing postal dosimeters for dose comparisons
    b. Providing on-site dosimetry audits
    c. Organize dose comparisons
    d. Providing calibration services for personal radiation dosimeters
    e. Providing postal dosimeters for patient dosimetry in diagnostic x-ray
    f. Supply sources to audit nuclear medicine calibrators

One of the main tasks of the SSDLs is the dissemination of codes of practice, guidelines or protocols, for the dosimetry of external beams used in radiotherapy, brachytherapy, diagnostic x-ray and radiation protection. IAEA develops and publishes dosimetry codes of practice for radiotherapy as the newest code of practice (IAEA, TRS-398). The SSDLs use and inform about other standards from the International Standardisation Organisation (ISO), the International Electrotechnical Commission (IEC), recommendations from the International Commission on Radiation Units and Measurements (ICRU) and other relevant international organisations. The SSDLs also give recommendations it selves.

5 Appendix Calibration and measurement capabilities

The calibration and measurement capabilities for services (either internal or external) are listed in tables A1 to A6. The reference instruments stated in the tables are secondary standards unless marked otherwise.

Table A 1 Radiation therapy, ^{60}Co. Unless stated otherwise, the reference instruments stated in the tables are secondary standards and high quality ionisation chambers, calibrated at a primary laboratory.

Radiation quality and quantity	Laboratory	Standard/traceability	MRA-CMCs status	Comments
^{60}Co **K_{air} and D_W**	NIRH	NE2561 / NPL	Not proposed	
	STUK	NE2561 / BIPM	Published	Calibration of ICs for linac megavoltage beams. IAEA TRS398 applied.
	NRPA	NE2561 and Cap PR-06G / BIPM	Proposed	In use
	SSI	NE2561 and NE2571/BIPM	Published	In use
Cross calibrations **Electron beam D_W**	STUK	NE2561 and PTW 30006 / BIPM and STUK	Published	Cross calibrations at linac electron beam at a RT clinic. IAEA TRS398 applied.
	NRPA	FC65-G / BIPM and NRPA	Not proposed	

Table A 2 X-ray radiation therapy and Brachytherapy. Unless stated otherwise, the reference instruments stated in the tables are secondary standards and high quality ionisation chambers, calibrated at a primary laboratory.

Radiation quality and quantity	**Laboratory**	**Standard/traceability**	**MRA-CMC status**	**Comments**
Xray 10 - 50 kVp, **K_{air}**	NIRH		Not proposed	
	STUK	PTW 23344 / BIPM	Published	In use
	NRPA	Radcal RC6M NE2536/3 / BIPM	Proposed	In use
	SSI	PTW 23344 Radcal 10X5-6M / BIPM	Published	25 - 50 kVp in use 10 kVp not in use at the moment
Xray 100 – 250 kVp, **K_{air}**	NIRH		Not proposed	
	STUK		Not proposed	No X-ray therapy in Finland at this range
	NRPA	Cap PR-06G / BIPM	Proposed	In use
	SSI	Exradin A3 / BIPM	Published	100 - 180 kVp in use
Brachytherapy **^{192}Ir** **Reference air kerma rate**	STUK	HDR 1000 Plus / Wisconsin –ADCL USA	Not proposed	In use. For high dose rate sources the calibrations are performed at hospitals.
	NRPA	K_{air} Co-60 and 250 kV HDR 1000 Plus Wisconsin –ADCL USA	Not proposed	In use
	SSI	HDR 1000 Plus / NPL	Not proposed	In use

Table A 3 X-ray diagnostics. Unless stated otherwise, the reference instruments stated in the tables are secondary standards and high quality ionisation chambers, calibrated at a primary laboratory.

Radiation quality and quantity	**Labora tory**	**Standard / traceability**	**MRA CMC status**	**Comments**
IEC X-ray qualities **K_{air}**	NIRH	Exradin A3 / PTB	Not proposed	RQR and RQA in use
	STUK	PTW 23344 / BIPM	Published	RQR qualities. Traceability to PTB (since 2006).
	NRPA	Cap PR-06G / BIPM	Not proposed	Some RQR set up not in service
IEC x-ray qualities **Kerma area product**	STUK	PTW 23344 / BIPM	Not proposed	RQR . Option: PTW Diamentor M4 / PTB
	SSI	PTW transmission chamber / PTB	Not proposed	RQR and RQA in use
IEC X-ray qualities **Kerma length product**	STUK	PTW 23344/ PTB	Not proposed	RQR. Traceability to PTB with RQR qualities (since 2006)

Table A 4 Radiation protection. Unless stated otherwise, the reference instruments stated in the tables are secondary standards and high quality ionisation chambers, calibrated at a primary laboratory.

Radiation quality	Laboratory	Quantity	Range	Standard / traceability	MRA CMC status	Comments
^{60}Co	NIRH					
	STUK	K_{air}, H*(10), $H_p(10)$	20 µSv/h – 3 Sv/h	NE 2575 PTB	Published	In use
	NRPA	K_{air}, H*(10), $H_p(10)$	0.1 Gy/h – 10 Gy/h	Exradin A2 BIPM	Proposed	In use
	SSI	K_{air}, H*(10), $H_p(10)$	14 Gy/h – 500 Gy/h	Exradin A2, Exradin BIPM	Published	In use
^{137}Cs	NIRH					
	STUK	K_{air}, H*(10), $H_p(10)$	20 µSv/h – 80 mSv/h	NE 2575 PTB	Published	In use
	NRPA	K_{air}, H*(10), $H_p(10)$	0.01 – 1 mSv/h	Exradin A2 BIPM	Proposed	In use
	SSI	K_{air}, H*(10), $H_p(10)$	4 sources 5 µGy/h – 90 mGy/h	Exradin A4 BIPM	Published	In use
^{241}Am	NIRH					
	STUK	K_{air}, H*(10), H'(0,07)	5 µGy/h – 45 µGy/h	NE 2575 PTB	Not proposed	In use
	SSI	K_{air}, H*(10), H'(0,07) $H_p(10)$, $H_p(0,07)$	40 µGy/h – 150 µGy/h	Exradin A5 NPL	Published	In use
X-ray ISO narrow series	NIRH					
	STUK	K_{air}, H*(10), $H_p(10)$, $H_p(0,07)$	1,7 mSv/h – 2,3 mSv/h	NE 2575 PTB	Published	Dose rate is according to the ISO narrow requirements. Higher doserates possible. 15 - 150 kV in use.
	NRPA	K_{air}, $H_p(10)$, $H_p(0,07)$	2 – 100 mGy/h	Capintec PM 30 NMi	Proposed	10 – 150 kVp in use
	SSI	K_{air}, $H_p(10)$, $H_p(0,07)$	0,7 – 25 mGy/h	Exradin A4 PTB	Published	40 – 150 kVp in use
X-ray ISO low dose rate series	NIRH					
	SSI	K_{air}, H*(10), H'(0,07)	15 µGy/h – 7 mGy/h	Exradin A4 PTB	Published	35 – 170 kVp in use

Table A 5 Radiation protection. Unless stated otherwise, the reference instruments stated in the tables are calibrated sources used as secondary standards.

Radiation quality	Laboratory	Quantity	Range	Standard / traceability	MRA CMC status	Comments
Beta rays ^{90}**Sr**	STUK	D_{tissue}	5 mGy/h - 350 mGy/h	Extrapolation ionisation chamber.	Yes	
	SSI	D_{tissue}	1µGy/h- 1 mGy/h	Calibrated sources./NPL		In use
^{85}**Kr**	NIRH	D_{tissue}	20 mGy/h	Extrapolation ionisation chamber	No	In use
	STUK	D_{tissue}	100 - 200 mGy/h	Extrapolation ionisation chamber	No	In use
^{204}**Tl**	STUK	D_{tissue}	0,1 - 0,5 mGy/h	Calibrated source. PTB	No	In use
	SSI	D_{tissue}	1 – 2 µGy/h	Calibrated sources./NPL		In use
^{147}**Pm**	STUK	D_{tissue}	0,1 - 1,0 mGy/h	Calibrated source. PTB	No	Source faded. Not in active use.
Neurons ^{241}**Am-Be**	STUK	H*(10),	30 - 300 µSv/h	Calibrated source, NPL	No	In use
	NRPA	H*(10)	1 – 10 µSv/h	Calibrated detector, PTB	No	Source used for stability test

Table A 6 Electrometers for measurements of low ionisation currents.

Laboratory	Quantity and range	Ref instr and traceability	MRA CMC status	Comments
STUK	pC, pA	Celsius Metech	Not proposed	Electrometers are not calibrated separately, only as a part of the dosimetry chain. For a user electrometer a sensitivity factor relative to the electronics at the laboratory can be delivered.
NRPA	pC, pA 10 – 50 000 pA	Resistors Keithley 5156 Voltage calibrator Fluke 343A Justervesenet	Not proposed	Electrometer and chamber are calibrated separately. The calibrations in beams are in range 50 – 150 pA and clinical use is ~ 1 nA.
SSI	pC, pA 0,1 – 1000 pA (depending on the uncertainty)	Home build electrometers traceable to the Swedish National Testing and Research Institute	Not proposed	Electrometers are not calibrated separately, only as a part of the dosimetry chain.

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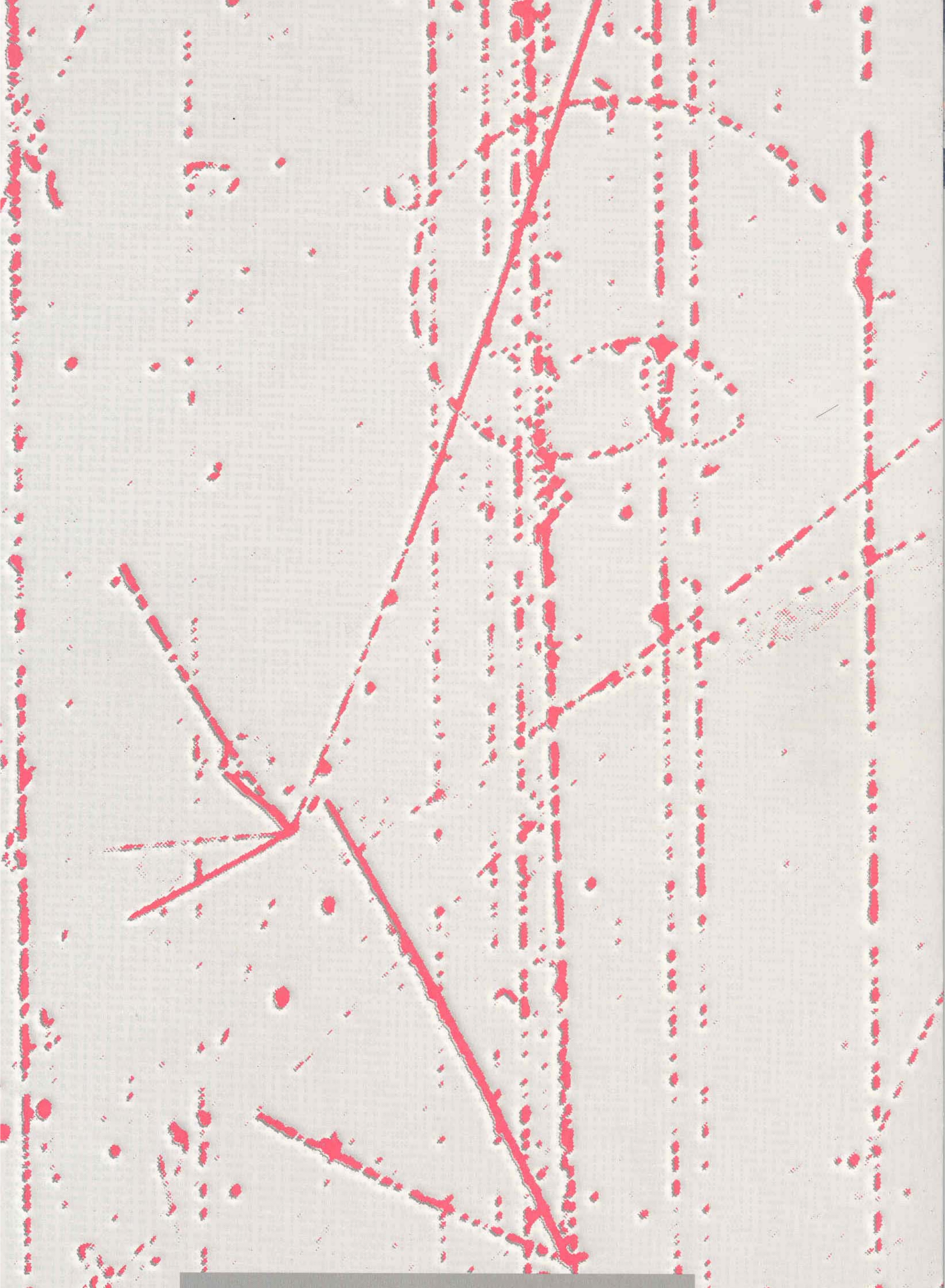

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