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Erkki Rantanen (ed.)

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The following have participated in the preparation of this report:
Ritva Havukainen
Eero Illukka
Kari Jokela
Hannu Järvinen
Petteri Jääskeläinen
Helinä Korpela
Mika Markkanen
Eero Oksanen
Olavi Pukkila
Erkki Rantanen
Eija Vartiainen
Eija Venelampi

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STUK – Radiation and Nuclear Safety Authority
P.O.Box 14, FIN-00881 HELSINKI
FINLAND
Tel. +358 9 759 881

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SUMMARY

There were a total of 1779 valid safety licences granted for the use of radiation in Finland in late 2000. Additionally, there were 2038 responsible parties for dental X-ray diagnostics (licence-free). The Safety Licence Register of the Radiation and Nuclear Safety Authority (STUK) listed 13 754 radiation devices and 270 radionuclide laboratories.

In 2000, STUK carried out 360 inspections of licensed practices and 53 inspections of licence-free dental X-ray practices. Repairs were ordered in 92 cases and recommended in 65 cases.

The import of radioactive substances amounted to 175 836 GBq and the export to 74 420 GBq. Short-lived radionuclides produced in Finland amounted to 55 527 GBq. The STUK interim storage for radioactive wastes received 37 batches of low-level wastes with a total mass of 1.9 tonnes.

In 2000, a total of 10 846 workers were individually monitored for radiation exposure at 1171 work-places. Of these workers, 27% received doses exceeding the recording level; no worker, however, received a dose exceeding the annual dose limit for the effective dose. The total dose recorded in the Dose Register of STUK was 6.5 Sv.

According to Decree of the Ministry of Social Affairs and Health, STUK issued reference levels for the most common diagnostic X-ray and nuclear medicine procedures. The mean doses in typical diagnostic X-ray procedures based on phantom measurements were below the reference levels issued by the Community, the IAEA and STUK. In radiotherapy, accuracy of the therapeutic doses underlying good therapeutic results has remained within acceptance limits, and no excessive doses jeopardizing the safety of therapy have occurred.

In the regulatory control of natural radiation, radon concentration measurements were performed in the workplaces of 59 employers, and radon inspections were performed in 4 underground mines and 1 excavation site. Additionally, the activity of 29 water samples was measured.

In the field of non-ionizing radiation, research activities mainly concerned the dosimetry of RF fields and pulsed magnetic fields.

In 2000, a total of 13 abnormal occurrences were investigated by STUK. Six of these were related to the use of radiation in industry, 1 to the medical use of radiation, 2 to the use of non-ionizing radiation, 2 to the nationwide radiation monitoring network and 2 to consumer goods.

CONTENTS

1 GENERAL

The use of radiation denotes the use of radiation equipment and radioactive substances in medicine, industry, research and teaching, as well as the import, export and production of and trade in radiation equipment and radioactive substances. Radiation practices signify, in addition to the use of radiation, any operations or circumstances in which a person's exposure to natural radiation causes or may cause a health hazard.

Under the provisions of the Radiation Act (592/1991), STUK – the Radiation and Nuclear Safety Authority – is the regulatory body for the use of radiation and other radiation practices in Finland. Regulatory control of the use of non-ionizing radiation is also covered by STUK unless specifically delegated to other authorities.

This report presents some events that occurred in 2000 concerning the use of ionizing and non-ionizing radiation, other radiation practices and their regulatory control. The report also presents annual statistics gathered by the Department of Radiation Practices Regulation (STO) and information on the metrological activities and regulative work of STO. Abnormal occurrences involving radiation are described as separate examples with the aim of avoiding such events in the future.

Appendix 1 contains the relevant list of current legislation governing radiation practices in Finland and Appendix 2 the most important regulations, decisions, directives and recommendations concerning radiation safety in the Community. Appendix 3 gives the training organizations that, in accordance with section 18 of the Radiation Act, have received STUK authorization to carry out qualification interviews for radiation safety officers and for other radiation users.

2 USE OF IONIZING RADIATION

2.1 Safety Licences and Radiation Sources

Under the provisions of the Radiation Act, the use of radiation is subject to a safety licence. Safety licences are granted by STUK upon application. There were 1779 valid licences in late 2000. STO maintains a Register of granted safety licences and the radiation sources included in the licences. Table *I* shows the number of safety licences and the number of practices in each specific category of use for which the licences are granted.

In addition, there were 2038 dental X-ray practices that are licence-free but made notifiable to STUK. Under STUK decision No. 202/310/99, dental X-ray practices no longer require safety licences if the following requirements are met:

1) the X-ray equipment must be equipped with a CE marking according to the Medical Devices Act (1505/1994) and the Medical Device Directive (93/42/EEC)
2) on-site radiation shielding complies with the requirements set in ST Guide 3.1
3) a dentist or physician is responsible for the X-ray equipment and its safe use.

Whenever the use of dental X-ray equipment does not comply with the above requirements, a safety licence is required. Fulfilment of these provisions is checked in conjunction with the registering of the equipment notified to STUK.

Tables *II–IV* give more detailed information on the radiation equipment, radiation sources and radionuclide laboratories included in the Safety Licence Register. The Register listed 13 754 radiation devices and 270 radionuclide laboratories. Compared with 1999, the number of devices was about the same, but there was a decrease of 3% in the number of laboratories. There were 6781 radiation devices for the medical use of radiation, the majority of which were X-ray devices. Veterinary X-ray equipment in use totalled 204. The majority of the 6973 radiation devices in use in industry, research, teaching and education were industrial devices containing sealed sources. Small sources with activities under exemption levels (such as calibration sources employed in laboratories) and radiation sources in the warehouses of importers were not individually registered.

Table I. *Number of safety licences and practices by specific categories of use, late 2000.*

Gategory	Number of safety licences	Number of practices
Medical use of radiation	**741**	
• X-ray diagnostics		471
• dental X-ray diagnostics		10[*)]
• veterinary X-ray diagnostics		184
• use of unsealed sources		66
• use of sealed sources		16
• radiotherapy		12
• other		15
Use of radiation in industry, research, teaching and education; trade in and installation and maintenance of radiation sources	**1038**	
• use of sealed sources (other than gamma radiography)		619
• use of unsealed sources		134
• import, export and trade		155
• installation, testing and maintenance		135
• use of X-rays (other than radiography)		168
• X-ray radiography		85
• gamma radiography		9
• production of radioactive substances		5
• other		14
Safety licences, total	**1779**	

[*)] Licences primarily granted for use other than dental X-ray practices.

Table II. *Number of radiation devices and radionuclide laboratories: medical and veterinary use of radiation, late 2000.*

Equipment/laboratories	Number
X-ray diagnostic equipment [*)]	**1593**
X-ray tubes	1922
1) in conventional X-ray diagnostics	1014
2) for particular purposes [**)]	908
• mammography (screening excluded)	102
• screening mammography	91
• computed tomography (CT)	70
• angiography (DSA excluded)	21
• digital subtraction angiography (DSA)	83
• bone densitometers	47
Dental X-ray equipment	**4877**
• intraoral X-ray units	4226
• panoramic X-ray units	651
Radiotherapy equipment	**73**
• linear accelerators	25
• Co-60 radiotherapy equipment	1
• afterloading equipment	8
• X-ray therapy equipment or radiographic equiment	17
• radiotherapy simulators	9
• other	13
Equipment with radioactive sources	**34**
• blood irradiation equipment	7
• bone densitometers	1
• calibration sources and other equipment	26
Veterinary X-ray equipment	**204**
Radionuclide laboratories	**100**
• type B laboratories	21
• type C laboratories	72
• other	7

[*)] One unit of X-ray diagnostic equipment consists of a high-voltage generator, one or more X-ray tubes and one or more examination stands.

[**)] Not all particular purposes are mentioned. Therefore, the total number of X-ray tubes given for particular purposes may not be the same as the sum of the tubes in those particular purposes that are mentioned here.

Table III. *Number of radiation devices and radionuclide laboratories: industry, research and education, late 2000.*

Equipment/laboratories	Number
Equipment containing radioactive substances	**6207**
• limit switches	2515
• density gauges	1034
• level gauges	915
• surface weight meters	622
• weight scales	479
• fluorescence analysers	138
• moisture and density gauges	117
• thickness gauges	58
• radiography equipment	21
• others	308
X-ray equipment and accelerators	**766**
• radiography equipment	349
• diffraction and fluorescence analysers	162
• fluoroscopic equipment	144
• other analysers	44
• others	67
Radionuclide laboratories	**170**
• type A laboratories	3
• type B laboratories	25
• type C laboratories	119
• others	23

Table IV. *Radionuclides most commonly used in sealed sources; number and total activities of sources, late 2000.*

Radionuclide	**Number of radiation sources**	**Total activity**[*)] **(GBq)**
Activity < 400 GBq		
Cs-137	3735	11 010
Co-60	1486	1590
Kr-85	407	5120
Am-241 (gamma sources)	323	2530
Pm-147	154	3440
Fe-55	151	439
Am-241 (Am/Be neutron sources)	98	1300
Sr-90	69	211
Cd-109	45	31
Cm-244	30	129
Activity 400–400 000 GBq		
Cs-137	23	655 000
Ir-192	20	55 800
Co-60	11	309 000[**)]
H-3	1	3700
Tm-170	1	1850
Pu-238 (Pu/Be neutron source)	1	888
Activity > 400 000 GBq		
Co-60	1	38 000 000[**)]

[*)] Sum of the nominal activities reported upon being taken into use. For short-lived radionuclides (e.g. Ir-192 and Tm-170), the extant total activities can be significantly less than nominal activities.
[**)] Activity on 31 December 2000.

1 GBq = 1 gigabecquerel = 10^9 Bq

2.2 Inspections of the Use of Radiation

With inspections at places where radiation is used, STUK oversees that legal regulations and the provisions given in safety licences are observed and that radiation practices are in every aspect carried out in a safe and acceptable way.

In the inspections, the inspectors ensure that the radiation equipment and the operations in which radiation is used meet the requirements placed upon them, that arrangements for radiation shielding, quality assurance and safety are adequate, maximum values or action levels given are not exceeded and that monitoring for radiation exposure and health surveillance of exposed workers are carried out according to relevant guides. Additionally, the inspectors ensure that radioactive materials and wastes are properly handled and that the users of radiation have been given adequate instructions for the use of radiation sources and in case of accidents. The results of every inspection are presented in a written document.

Radiation sources and their use are usually inspected for the first time when radiation practice is initiated. After the start-up inspection, periodic inspections are carried out at intervals of 1–5 years, depending on the practice.

In 2000, STUK performed 360 inspections of licensed practices and 53 inspections of licence-free dental X-ray practices. The numbers of inspections classified according to the type of inspection are given in Table *V*. The numbers of inspections of licensed practices classified according to the type of practice are given in Table *VI*.

During the inspections, 92 repairs were ordered and 65 repairs were recommended. No equipment was prohibited from use, but the use of 1 dental X-ray device was limited. Remarks (repair orders and recommendations) and their numbers are given in Table *VII*. No remarks were given in 260 inspections.

Table V. *Inspections of the use of radiation in 2000.*

Type of inspection	**Number of inspections**	
	Licensed practices	**Dental X-ray practices**
Start-up inspection	126	1
Periodic inspection	219	16
Reinspection	10	0
Other inspection or measurement	5	36
Total	**360**	**53**

Table VI. *Inspections of licenced practices in 2000.*

Type of practice	Number of inspections
Medical use of radiation	
• X-ray diagnostics	199
• dental X-ray diagnostics	9
• veterinary X-ray diagnostics	17
• use of unsealed sources	15
• use of sealed sources	1
• radiotherapy	32
• other	0
Use of radiation in industry, research and teaching; trade in and installation and maintenance of radiation sources	
• use of sealed sources (other than gamma radiography)	65
• use of unsealed sources	6
• import, export and trade	0
• installation, testing and maintenance	0
• use of X-rays (other than radiography)	5
• X-ray and gamma radiography	11
• production of radioactive substances	0
• other	0
Total	**360**

Table VII. *Remarks given in inspections and their numbers.*

Subject of remark	Number of remarks	
	Licensed practices	Dental X-ray practices
Remarks concerning licence, registaration or organization		
• licence or registration	11	5
• radiation safety officer or dentist	3	0
• instructions for use or safety	2	0
• individual monitoring and health surveillance	1	0
• other	1	1
Remarks concerning radiation equipment or practice		
• function of equipment and its shielding arrangements	22	20
• handling of radioactive substances and wastes	3	0
• premises	4	0
• quality assurance	24	0
• safety arrangements	13	0
• auxiliary equipment and actions	16	8
• patient doses	6	0
• other	14	4
Total	**120**	**38**

2.3 Import, Production and Export of Radioactive Substances

For regulatory purposes, STUK annually requires information on the trade in radioactive substances from manufacturers and importers involved. Based on Council Regulation (Euratom) No. 1493/93, STUK receives information on radioactive substances imported into Finland from within the Community directly from the consignors*). Tables *VIII–X* give information on the amounts of radionuclides imported, produced and exported in 2000.

The total activity of imported radioactive substances in 2000 was 175 836 GBq (Table *VIII*). Large sources (activities more than 4000 GBq) were not imported into Finland in 2000. Radioactive substances are mainly imported into Finland from within the Community (about 90% according to an enquiry in 1999).

The number of imported smoke detectors and ionization detectors used in fire detection systems containing ^{241}Am was 1 082 000. The total activity of the detectors was 33 GBq.

Short-lived radioactive substances (unsealed sources) produced in Finland in 2000 amounted to 55 527 GBq (Table *IX*). This represented an increase of about 6% compared with the previous year.

The total activity of exported substances was 74 420 GBq (Table *X*). The exported items comprised consumer goods containing tritium, analysers with sealed sources, radiopharmaceuticals and decommissioned radiation sources (for return to manufacturers).

Radioactive substances delivered through Finland to other countries are not included in the import and export statistics. For example, radiopharmaceuticals to the Baltic countries are transported through Finland.

*) In the Community, the term “shipment of radioactive substances” is used to denote import and export of radioactive substances between the Member States. In this chapter the terms “import” and “export” are used irrespective of the country of departure or destination.

Table VIII. *Imported radioactive substances in 2000.*

Radionuclide	**Activity (GBq)**		
	Unsealed sources	**Sealed sources**	**Total**
H-3	271	59 870	60 141
Ir-192	4	56 988	56 992
Mo-99	41 463	-[*)]	41 463
I-131	7150	-	7150
Sm-153	3015	-	3015
Ho-166	1394	-	1394
Kr-85	-	1265	1265
Pm-147	-	1045	1045
Tc-99m	750	-	750
I-125	602	-	602
Cs-137	-	345	345
Fe-55	22	255	277
I-123	251	-	251
Tl-201	220	-	220
P-32	208	-	208
Xe-127	176	-	176
W-188	109	-	109
S-35	99	-	99
Cd-109	-	66	66
Xe-133	65	-	65
Am-241	-	57	57
Co-60	-	36	36
In-111	30	-	30
Others, total[**)]	45	35	80
Total import	**55 874**	**119 962**	**175 836**

[*)] "-" means there was no import.

[**)] Nuclides: Ba-133, C-14, Ca-45, Cf-252, Cm-244, Co-57, Cr-51, Cu-64, Eu-152, Fe-59,Ga-67, Gd-153, Ge-68, I-129, Na-22, Ni-63, P-33, Po-210, Ra-226, Rb-86, Re-186, Se-75, Sr-85, Sr-89, Sr-90 and Y-90.

Table IX. *Production of radioactive substances (unsealed sources) in 2000.*

Radionuclide	**Activity (GBq)**
O-15	40 500
C-11	8770
F-18	5508
Br-82	733
Na-24	10
La-140	4
Au-198	2
Others, total[*)]	< 1
Total production	**55 527**

[*)] E.g. nuclides: Ar-41 and Cd-109.

Table X. *Export of radioactive substances in 2000.*

Radionuclide	**Activity (GBq)**
H-3	56 023
Ir-192	9096
Mo-99	6372
I-131	1160
Kr-85	705
Pm-147	224
Fe-55	211
Sm-153	142
Xe-127	93
Cs-137	92
Cd-109	56
Ho-166	55
Y-90	54
I-123	50
W-188	47
Others, total[*)]	40
Total export	**74 420**

[*)] Nuclides: Am-241, C-14, Cm-244, Cu-64, Eu-152, Ga-67, I-125, I-129, In-111, Ni-63, Sr-90 and Tl-201.

2.4 Radioactive Wastes

STUK maintains a national storage facility for the safekeeping of solid, low-level radioactive wastes. The facility is located in conjunction with the intermediate- and low-level nuclear waste repository of the Olkiluoto Nuclear Power Plant owned by Teollisuuden Voima Oy. The facility is a separate part of the Olkiluoto repository, reconstructed for low-activity wastes and rented to STUK. The facility was taken into use in spring 1997. By late 2000, a total of 142 waste parcels with a total mass of 40.6 tonnes were transported to the facility. The activities or the mass of the most remarkable wastes in the facility are given in Table *XI*.

Before the wastes are taken to the Olkiluoto facility, they are transported to an interim storage unit situated in the STUK premises at Roihupelto, Helsinki. According to radiation regulations, the user of the radiation source is responsible for the transport and, in general, for ensuring that the radioactive waste produced is rendered harmless through the implementation of proper safety procedures. Transport of wastes is carried out according to the regulations given for the transport of dangerous materials (regulations according to the ADR agreement).

In 2000, the STUK interim storage received 37 batches of low-level wastes consisting of a total of 70 parcels. The total mass of the parcels was 1.92 tonnes. Table *XII* gives the activities or the mass of the wastes received by STUK in 2000.

Table XI. *The most remarkable low-level radioactive wastes in the Olkiluoto facility (December 2000).*

Radionuclide	**Activity (GBq) or mass**
H-3	21 150
Co-60	277
Kr-85	765
Sr-90	146
Cs-137	1453
Ra-226	229
U-238	164 kg
Pu-238	1405
Am-241	618

Table XII. *Low-level radioactive wastes received by STUK in 2000.*

Radionuclide	Activity (GBq) or mass
H-3	7.4
Co-60	11.0
Ni-63	0.5
Kr-85	111
Sr-90	3.6
Cs-137	57.0
Pm-147	5.1
Ra-226	0.01
U-238	70.0 kg
Am-241	19.3
Cf-252	0.02

2.5 X-ray Diagnostics

During inspections of X-ray diagnostics performed by STUK in 2000, no serious shortcomings in safety arrangements were found and no notifications of emergency situations were made. In general, the level of safety in X-ray diagnostics can be considered rather good, although patient doses still exhibit considerable (as much as 10-fold) variation in level from place to place. This variation can usually be reduced without jeopardizing the purpose of the medical procedure involved. The reduction calls for procedures carried out with increased awareness of safety and optimization of diagnostic methods.

As a result of the recommendations given, the highest patient doses have become substantially lower in nearly all cases studied. In CT tomography it is not possible, for technical reasons, to diminish patient doses in some cases without noticeably deteriorating the image quality.

STUK found no cases of unjustified use in X-ray diagnostics in 2000.

Reference levels for X-ray diagnostics

In 2000, STUK issued reference levels in its letter No. 596/310/00 covering examinations in X-ray diagnostics and nuclear medicine. This was done to fulfil the provisions of the Decree on the Medical Use of Radiation (423/2000), issued by the Ministry of Social Affairs and Health. Table *XIII* gives the reference levels of STUK for some common X-ray examinations and the corresponding reference levels given in the report of the EC expert group in 1996[*)]. A reference level means a dose that is not supposed to be exceeded when a standard patient (about 70 kg) is examined. If the dose in some case is higher than the reference level, then it should be determined if the dose is too high and if it could be diminished without deteriorating the result of the examination.

Inspections of fluoroscopic units

A total of 18 fluoroscopic units (3% of all units) were inspected in 2000. The air kerma rate and the quality of the fluoroscopic image of all the units were satisfactory according to the grading scale set in ST Guide 3.3. The results for 1996–2000 are shown in Table *XIV*.

[*)] European Guidelines on Quality Criteria for Diagnostic Radiographic Images, EUR 16260 EN, European Commission, June 1996.

Table XIII. *Reference levels for some common X-ray examinations.*

Projection	**Reference level (mGy)** *)	
	STUK	**EC**
Thorax PA	0.2	0.3
Thorax LAT	1	1,5
Lumbar spine AP	8	10
Lumbar spine LAT	25	30
Lumbar spine LSJ (LV-S1)	35	40
Pelvis AP	8	10
Urography (per image)	8	10
Abdomen AP (standing)	8	-
Breast **) CC, MLO, LAT	10	10
Skull PA	5	5
Skull LAT	3	3
Paranasal sinuses, semi-axial	5	-
Intraoral, upper molar	5	-

*) Reference level means the absorbed dose on the skin (Entrance Surface Dose, ESD).
**) A grid in use.

Table XIV. *Air kerma rate and image quality of fluoroscopic units, 1996–2000.*

Year	**Number of inspected units**	**Air kerma rate, (μGy·s^{-1})** **Mean (range)**	**Image quality**	
			Contrast sensitivity, (mm Al) Mean (range)	**Spatial resolution, (line pairs·mm^{-1}) Mean (range)**
1996	22	0.43 (0.16–0.76)	*)	*)
1997	18	0.39 (0.15–0.66)	0.24 (0.20–0.40)	1.25 (0.70–1.80)
1998	28	0.34 (0.08–0.70)	0.30 (0.20–0.60)	1.23 (< 0.60–2.20)
1999	14	0.44 (0.11–1.60)	0.27 (0.20–0.40)	1.16 (< 0.70–1.60)
2000	18	0.31 (0.13–0.63)	0.23 (0.20–0.30)	1.30 (0.90–1.80)
Requirement in ST Guide 3.3		< 0.8	$\leq$ 0.6	$\leq$ 0.7

*) 1996 results for image quality have not been gathered.

Regulatory control of dental X-ray units

As part of the regulatory control of dental X-ray units, test packages are posted to dental X-ray users every 3–5 years. Through measurement of returned packages, information is obtained among other things on radiation doses in praxis. More information on the measurements is given in the Radiation Practices Annual Report 1995 (STUK-B-STO 33).

In 2000, measurements of molar X-ray doses were taken in 839 dental X-ray units. The doses correspond to the entrance dose on the surface of the cheek when a molar tooth is X-rayed. Figure 1 shows the distribution of the measured doses; the mean dose was 4.2 mGy and the range of doses 0.7–19.5 mGy. The reference value recommended by the IAEA (International Atomic Energy Agency)[*)] for the limit of a dental X-ray dose is 7 mGy (reference value for the Entrance Surface Dose). The corresponding reference level given by STUK is 5 mGy (see Table *XIII*). A total of 12% of the X-ray units measured in 2000 exceeded the value of 7 mGy and 27% exceeded the reference level of 5 mGy. A dose of 5 mGy in dental X-rays is equivalent to an effective dose of about 7 μSv.

During 1995–2000, the dose-area-products of 131 dental panoramic X-ray units were measured. Figure 2 shows the distribution of the measured dose-area-products; the mean dose was 96 mGy·cm^2 and the range of doses 34–254 mGy·cm^2. The reference level given by STUK for the dose-area-product is 120 mGy·cm^2; 15% of the units measured exceeded this value.

[*)] International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. Safety Series No. 115, Schedule III, p. 279, International Atomic Energy Agency (IAEA), Vienna 1996.

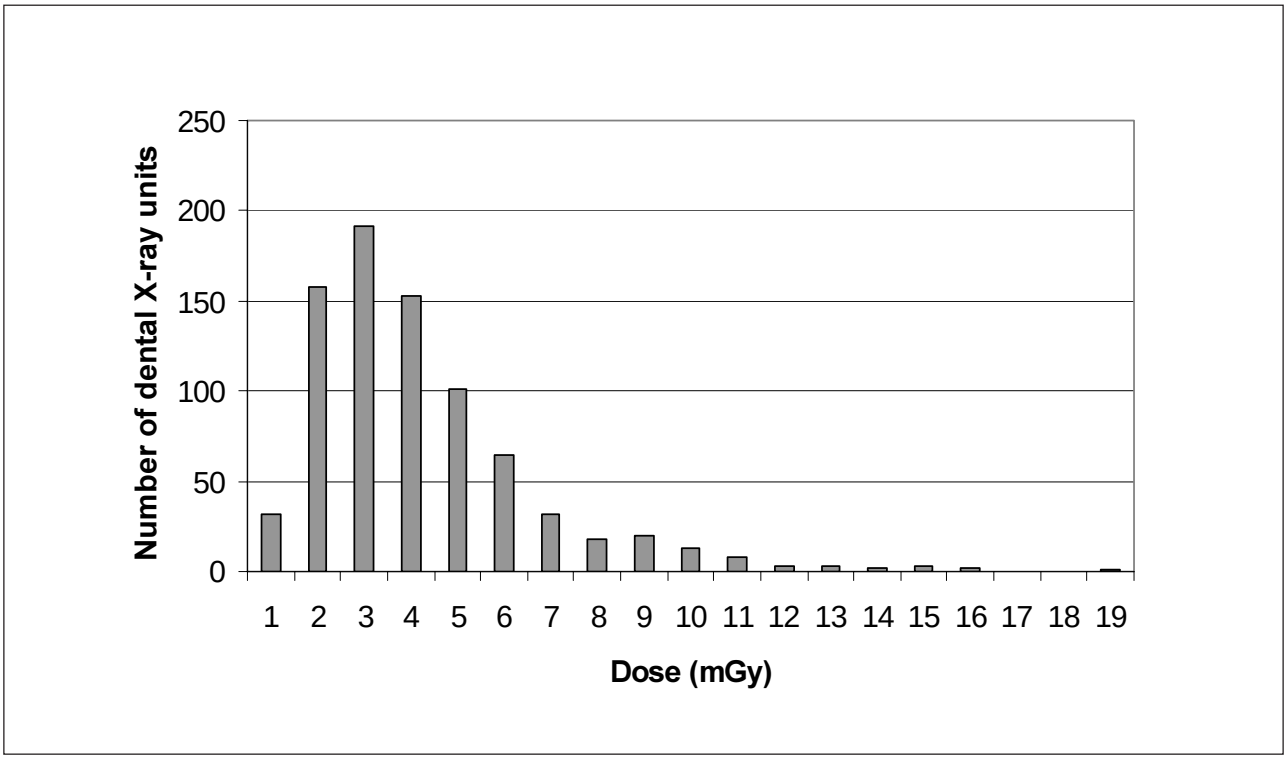

Figure 1. *Dose distribution of dental X-ray measurements, 2000.*

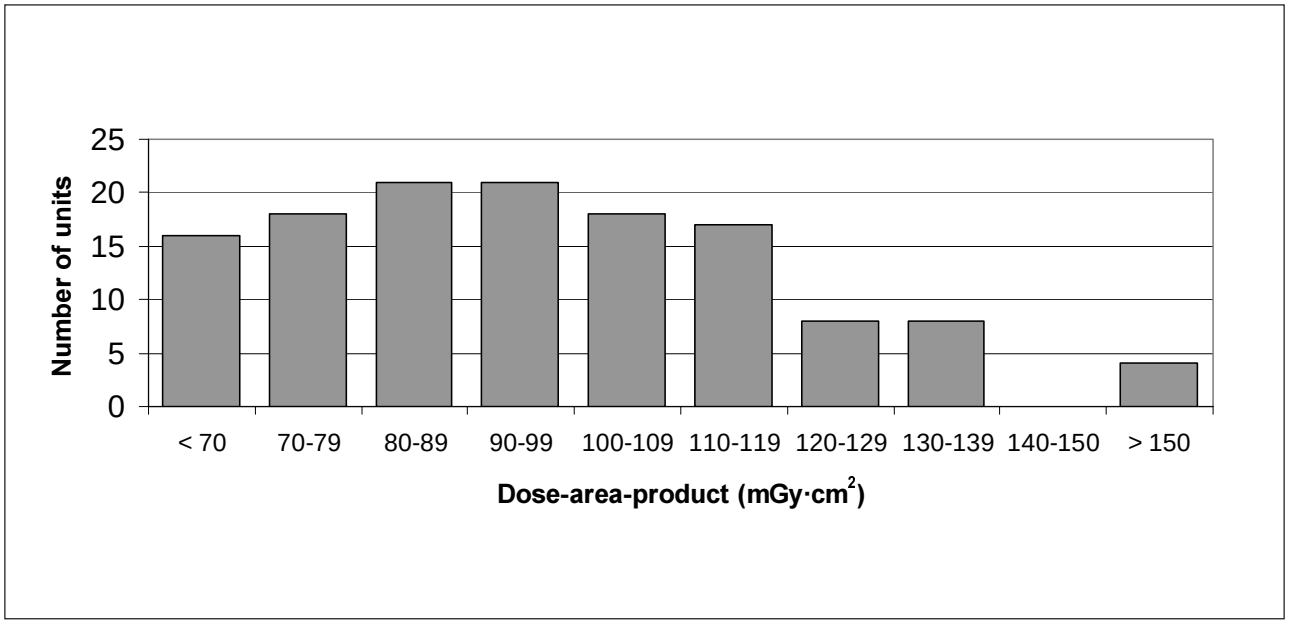

Figure 2. *Dose-area-product distribution of dental panoramic X-ray measurements, 1995–2000.*

Patient dose and image quality studies

In its inspections during recent years, STUK has studied patient doses and image qualities in common X-ray examinations. In these studies a phantom and the technique adopted by the particular user were utilized to measure the ESDs and some parameters of the image quality. In 2000, measurements were taken for lumbar spine AP and chest PA projections in 20% of X-ray wards.

Table *XV* gives the ESDs measured in the inspections during 1995–2000. The Table also shows the reference values given by the EC expert group (see section on Reference levels for X-ray diagnostics, page 17) and the reference levels given by STUK. The mean doses are lower than the STUK reference levels for these examinations. Figures 3 and 4 give the dose distributions of the measurements in 2000.

The EC expert group has also given recommendations for X-ray image quality. These recommendations, however, are for clinical X-ray images. There are no international reference values for technical image quality. The national status of technical image quality can be estimated by comparing the results of image quality measurements conducted in various years.

Table *XVI* gives the results of image quality measurements for 1995–2000. The measurements were performed with the phantoms and measuring methods given in ST Guide 3.5. No essential differences can be seen on the basis of these results.

Table XV. *Radiation doses on the surface of the phantom in lumbar spine and chest X-ray, 1995–2000.*

Year	Dose[*] (mGy) Mean (range)	
	Lumbar spine AP	**Chest PA**
1995	6.0 (2.4–13)	0.19 (0.04–0.52)
1996	6.0 (2.3–16)	0.14 (0.06–0.36)
1997	4.7 (1.1–12)	0.12 (0.03–0.30)
1998	6.0 (0.4–26)	0.12 (0.03–0.47)
1999	5.4 (1.1–11)	0.13 (0.03–0.33)
2000	5.9 (0.7–23)	0.13 (0.04–0.44)
EC reference value[**]	10	0.3
STUK reference level	8	0.2

[*] Dose on the surface of the phantom (Entrance Surface Dose).
[**] Normal-sized, 70-kg patient.

Table XVI. *Image quality in lumbar spine and chest X-ray, 1995–2000.*

Year	Optical density (OD) Mean (range)		Contrast (OD) Mean (range)		Spatial resolution (line pairs·mm^{-1}) Mean (range)	
	Lumbar spine AP	**Chest PA**	**Lumbar spine AP**	**Chest PA**	**Lumbar spine AP**	**Chest PA**
1995	1.30 (0.59–2.25)	1.66 (0.74–2.4)	0.21 (0.09–0.35)	0.30 (0.20–0.40)	2.1 (1.4–2.8)	3.7 (3.1–5.0)
1996	1.24 (0.67–2.16)	1.53 (0.72–2.35)	0.21 (0.11–0.29)	0.33 (0.24–0.49)	2.0 (1.2–2.8)	3.9 (2.6–5.0)
1997	1.23 (0.67–1.83)	1.43 (0.63–2.21)	0.24 (0.12–0.40)	0.32 (0.20–0.47)	2.2 (1.2–4.0)	3.8 (2.0–5.0)
1998	1.31 (0.52–2.27)	1.60 (0.43–2.39)	0.22 (0.06–0.50)	0.31 (0.10–0.52)	2.2 (1.0–4.3)	3.9 (2.2–5.0)
1999	1.26 (0.66–1.97)	1.64 (1.06–2.33)	0.25 (0.06–0.47)	0.30 (0.13–0.54)	2.0 (0.8–3.1)	3.7 (1.4–5.0)
2000	1.22 (0.58–1.88)	1.67 (0.60–2.26)	0.22 (0.08–0.39)	0.30 (0.08–0.52)	2.2 (0.9–4.3)	3.9 (1.8–5.0)

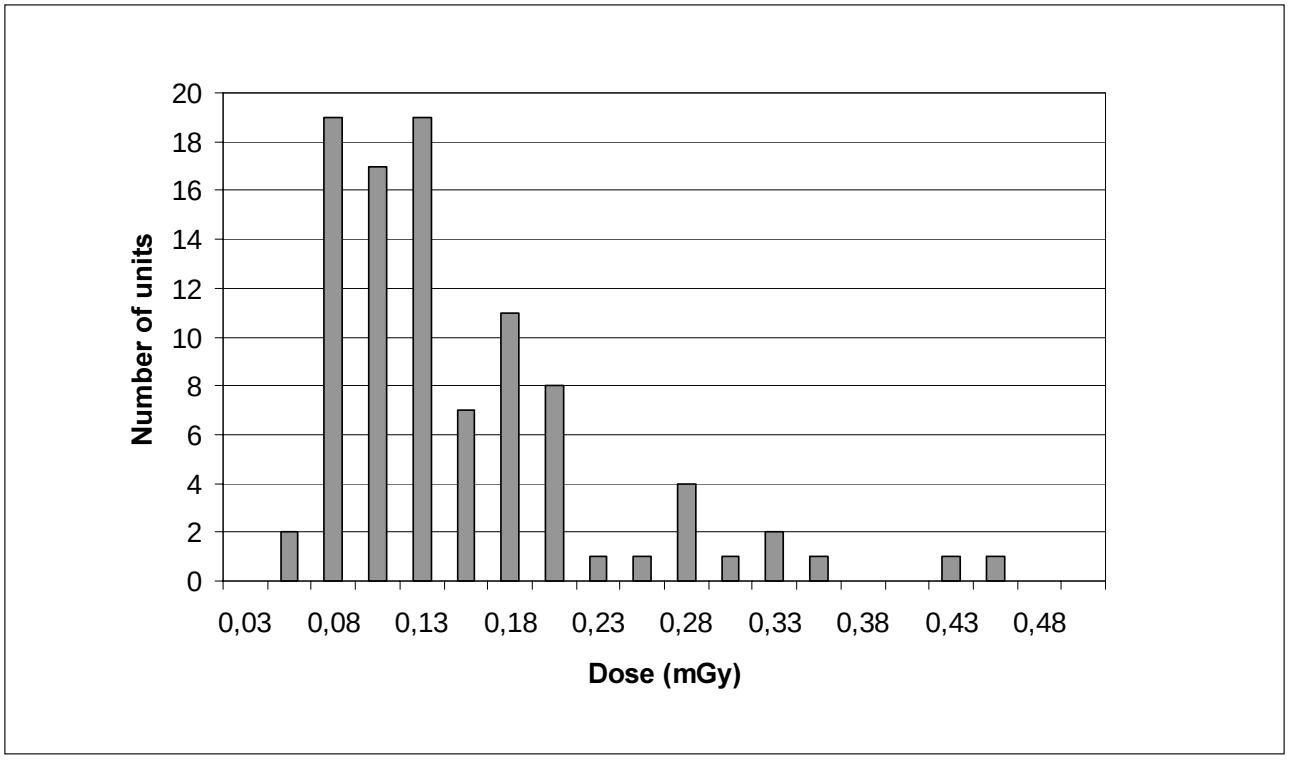

Figure 3. *Dose distribution of chest X-ray measurements, 2000.*

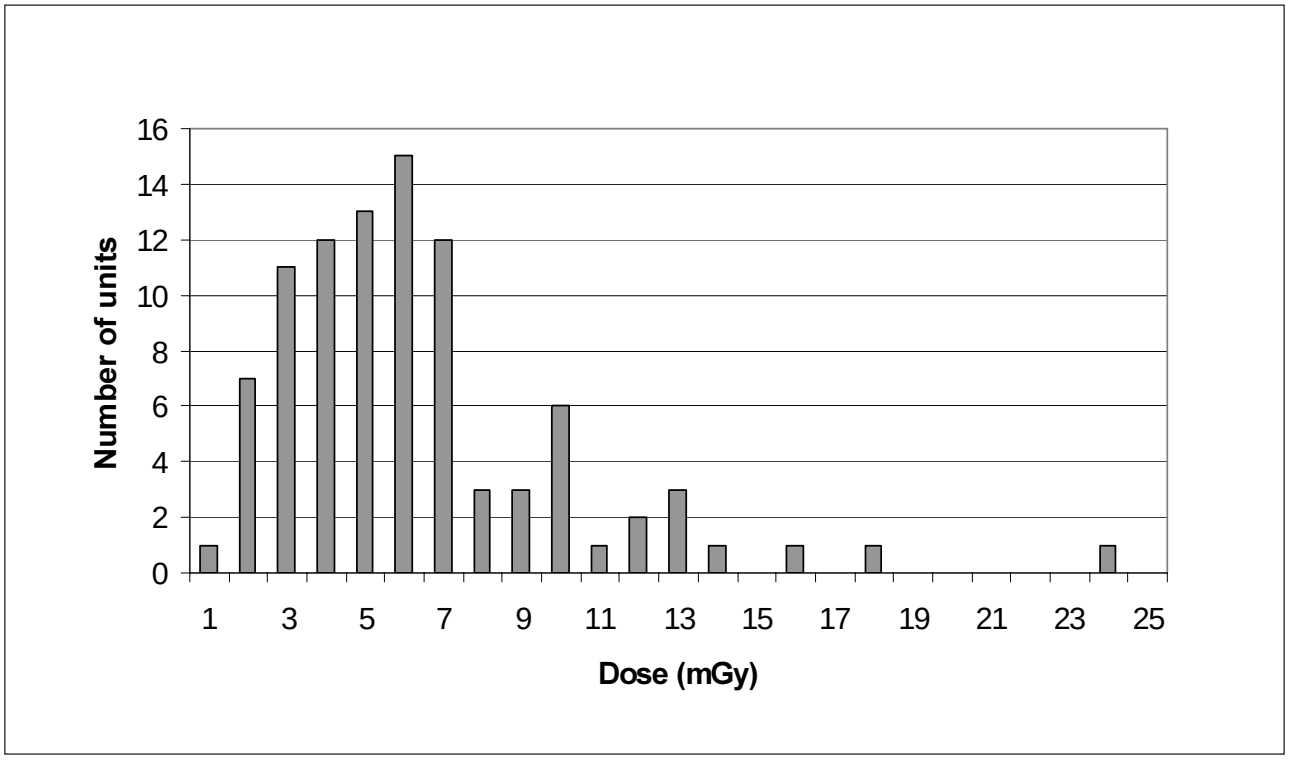

Figure 4. *Dose distribution in lumbar spine X-ray measurements, 2000.*

2.6 Nuclear Medicine

Reference levels for nuclear medicine examinations

In its letter on the reference levels for X-ray diagnostics and nuclear medicine (see section on Reference levels for X-ray diagnostics, page 17) STUK issued reference levels for 17 nuclear medicine examinations. The fraction of activity administered to adults that should be administered to children was given as a function of the weight of the child. In addition, minimum activities to be administered to children for some radiopharmaceuticals were also given.

A reference level for a nuclear medicine examination means a level of activity, defined in advance, that is not expected to be exceeded for a standard-sized patient in a standard procedure when good and normal practice is applied. Reference levels are not meant to be applied to limit the radiation exposure of an individual patient. The use of higher activities is justified only for medical reasons. If the activity administered to a patient in a particular examination is remarkably lower than the reference level, it should be ascertained that the requested diagnostic information is obtained. The use of reference levels is a new instrument for optimization.

The diagnostic information from a nuclear medicine examination varies with the amount of administered activity. There is a threshold of administered activity below which no useful information can be expected. Above this threshold, the diagnostic information increases steeply with increasing activity, until the optimum activity is reached. Once the optimum activity is reached, a further increase in the administered activity will only increase the dose to the patient, but not the value of the diagnostic information.

The aim is to use activities that are as near the optimum as possible. In practice, the amount of administered activity is mainly based on local experience and tradition, and therefore there are considerable differences in activities used in different laboratories in the same nuclear medicine examination. Table *XVII* shows the mean activity administered in some nuclear medicine examinations in Finland in 1997 weighted with the number of examinations and the range of reported mean activities used in different laboratories[*)]. To begin with, the aim of using reference levels is to eliminate the highest activities administered. When experience in the use of reference levels has been obtained, new reference levels can be given, if necessary. At first, reference levels were given for such nuclear medicine examinations the number of which is large and which, therefore, cause a high collective effective dose or for such examinations that result in a high dose to an individual patient. When determining the first national reference levels, the results of the survey made by STUK concerning the use of radiopharmaceuticals in 1997 in Finland were used.

As an example, the mean activities used in lung perfusion imaging in different laboratories with ^{99m}Tc-MAA (macroaggregated albumin labelled with ^{99m}Tc) are shown in Table *XVIII*. It can be seen that the mean activity administered in lung perfusion imaging in 1997 varies from 50 to 222 MBq. The chosen reference level in Finland is 150 MBq. Thus, in about 10% of lung perfusion imaging examinations performed in 1997 the activity administered was higher than the given reference level.

In Table *XIX*, some reference levels for nuclear medicine examinations in Finland have been compared to the reference levels given by the NRPB (National Radiological Protection Board)[**)] in the United Kingdom and to the maximum usual activities given by the IAEA (see footnote on page 19).

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*) H. Korpela, Use of radiopharmaceuticals in Finland in 1997, STUK-B-STO 38, Radiation and Nuclear Safety Authority, Helsinki 1999.

**) Notes on Guidance on the Clinical Administration of Radiopharmaceuticals and Use of Sealed Radioactive Sources. National Radiological Protection Board (NRPB), 1998.

Table XVII. *Mean administered activity (weighted with the number of examinations) in some nuclear medicine examinations in different laboratories in Finland in 1997 and range of the mean administered activities.*

Examination	**Radionuclide/ Radiopharmaceutical used**	**Mean administered activity (MBq)**	**Range (MBq)**
Bone imaging	Tc-99m/phosphates and phosphonates	595	100–740
Bone imaging, SPECT	Tc-99m/phosphates and phosphonates	727	500–740
Renal imaging	Tc-99m/DTPA	166	74–370
Brain perfusion, SPECT	Tc-99m/HMPAO	733	600–900
Thyroid imaging	Tc-99m/pertechnetate	122	74–185

Table XVIII. *Mean administered activities in lung perfusion imaging (^{99m}Tc-MAA) in different laboratories in 1997 and the number of laboratories and examinations. The reference level is 150 MBq.*

Mean administered activity (MBq)	**Number of laboratories**	**Number of examinations**
50	1	137
60	1	916
74	1	406
75	3	708
80	2	322
100	2	408
110	3	450
111	5	836
120	1	293
148	2	341
150	3	544
185	3	235
222	1	390

Table XIX. *Reference levels for nuclear medicine examinations in Finland and reference levels given by the NRPB and maximum usual activities recommended by the IAEA for the same examinations.*

Examination	Radio-nuclide	Radio-pharmaceu-tical	Reference level in Finland (MBq)	Reference level of NRPB (MBq)	Maximum usual activ-ity (IAEA) (MBq)
Bone imaging	Tc-99m	phosphates	600	600	600
Infection imaging	Tc-99m	leukocytes	300	200	400
Lung perfusion imaging	Tc-99m	MAA	150	100	100
Renal imaging	Tc-99m	MAG3	150	100	100
	Tc-99m	DTPA	300	300	350
Myocardial perfusion, SPECT	Tl-201	chloride	100	80	100
	Tc-99m	MIBI	1000*)	1000*)	-
Brain perfusion, SPECT	Tc-99m	HMPAO	740	500	500
Thyroid imaging	Tc-99m	pertechne-tate	150	80	200
	I-123	iodide	20	20	20
Thyroid metastases	I-131	iodide	400	400	400
Parathyroid imaging	Tc-99m	MIBI	740	900	-

*) Total activity administered in a single day.

2.7 Radiotherapy

General

In radiotherapy, the aim is to eradicate a local tumour with minimum damage to the surrounding healthy tissue. For this aim to be achieved, the prescribed radiation dose must be delivered to the target volume as precisely as possible. According to international recommendations, e.g. given by the ICRU (International Commission on Radiation Units and Measurements), the uncertainty of the dose to the patient should not exceed 5% on the average. Regulatory activities to ensure proper implementation of the principles of justification and optimization at hospitals thus concentrate on those factors that affect the accuracy (i.e. correct value and targeting) of the dose to the patient.

To ensure the high accuracy of the dose to the patient, quality assurance (QA) programmes are required in radiotherapy departments. The Decree on the Medical Use of Radiation, issued by the Ministry of Social Affairs and Health in 2000, assigns a number of new responsibilities to the users. Implementation of these requirements at radiotherapy clinics requires that attention be directed to the quality management of the entire radiotherapy process, in addition to the technical QA programmes. In practice, this is equivalent to establishing a quality system in accordance with international quality standards. In the regulatory control of radiotherapy, therefore, attention is also focused on the development of comprehensive quality systems for radiotherapy.

Inspections

The functioning and results of QA programmes are regularly evaluated by STUK inspections. In 2000, all departments had implemented and were running the QA programmes in accordance with STUK requirements. A detailed quality-control

programme approved by STUK has been set up for each radiotherapy equipment that has been in use for at least 1 year.

In 2000, a total of 36 devices were inspected in radiotherapy departments, 5 of which were for the acceptance of new equipment. Based on the inspections and related measurements of radiation protection, it can be concluded that the radiation safety of personnel and patients has remained good. Furthermore, the results of the inspections and comparative measurements of the characteristics of radiotherapy equipment (treatment equipment and simulators) indicate that the procedures applied and the characteristics of equipment affecting patient dose accuracy have, in general, met established requirements. Four remarks on the shortcomings in radiation safety arrangements, radiotherapy equipment or quality-control methods were recorded. In the comparative dose measurements in electron beams, the acceptable level (2%) was exceeded in 2 electron beams. In the inspections of 13 treatment-planning systems, no deviation of greater than 5% between the measured and calculated doses was observed. Based on findings of the accuracy of dose delivery, implementation of the principles of justification and optimization in radiotherapy can be considered good.

Development of quality systems

The national guide on how to establish a quality system for radiotherapy, prepared by a group of radiotherapy experts convened by STUK, was finalized on the basis of comments from radiotherapy departments and published. In the guide, the basic principles of quality systems are introduced, with practical advice and examples of how to implement a system. The guide is based on the recommendations of the ESTRO (European Society for Therapeutic Radiology and Oncology) and, accordingly, on the ISO 9000 series of quality standards but tailored to the needs of radiotherapy.

The plans of the radiotherapy departments for establishing and implementing quality systems were evaluated with the help of an enquiry sent to the heads of the departments. A summary of the replies to the enquiry was sent for information to the Ministry of Social Affairs and Health.

The radiotherapy departments consider it essential to establish quality systems, and the current motivation for their implementation is good. Development of a quality system has been initiated in all radiotherapy departments, while there is wide variation in the progress of the work. Only one department has completed the quality system, as part of the quality system of the central hospital and the healthcare district, and this system has also been certified by the Finnish Standards Association (SFS). In 3 other departments, the quality system is estimated to be completed during the next 2 years, while the other 5 departments are just beginning this task. In most departments, development has been independent with no direct link to development of the quality system in the relevant hospital or healthcare district. The main problem in development has become one of personnel resources, which have not been available in the overloaded departments without extra funding. Another problem has been the arrangement of necessary training for quality matters: on the one hand, this is due to the costs of training, and on the other to the difficulties in finding suitable expert training.

Research

STUK is currently participating in a research project “A Code of Practice for Dosimetry of Boron Neutron-Capture Therapy (BNCT) in Europe”, partly financed by the Community. The aim of the project is to create and publish European measurement recommendations for harmonizing the dosimetry of BNCT. In the project, STUK´s responsibilities are mainly to establish a metrologically acceptable method of BNCT dose measurements and to be responsible for preparation of the recommendations for publication. The project has continued with the planning of a test and comparison programme for the methods of measurement, for which STUK acquired a microdosimetric device. The European recommendations are scheduled to be completed by late 2002.

Training and cooperation with national counterparts

In 2000, STUK organized the following meetings and training sessions related to the regulatory control of radiotherapy:

- The annual meeting with radiotherapy physicists in Naantali. The main topics were implementation of Community Directives into Finnish legislation, the quality systems for radiotherapy and the education and training of radiotherapy physicists. In addition, STUK's research projects related to the regulatory control of radiotherapy were discussed.
- A special meeting on basic dosimetry in radiotherapy was organized on 25–26 October 2000 in Tampere, in collaboration with the Tampere University Hospital. The main topics were measurements for calibration and quality control of radiotherapy equipment. The participants were mainly assistant physicists who are practising for a radiotherapy physicist profession.

International cooperation

STUK is participating in work of the ICRU Report Committee, which aims at preparing recommendations for the dosimetry of beta rays in radiotherapy applications. Handling of the draft report prepared by the Committee was continued by acquiring comments from outside experts. The draft report has been estimated to be completed in 2001. Furthermore, a representative of STUK participates in the work of WG 1 of SC 62C of the IEC (International Electrotechnical Commission), dealing with the standardization of radiotherapy equipment.

A representative of STUK participates in the ESTRO Physics Committee and in a working group established by the ESTRO and funded by the Community for development of comparative measurements in radiotherapy. Almost all radiotherapy departments in Finland participated in these ESTRO comparative measurements; the results will be analyzed in 2001.

In 2000, the STUK experts visited the Estonian Cancer Centre in Tallinn to aid in the calibration of brachytherapy equipment and participated as experts invited by the IAEA for the evaluation of radiotherapy departments in Lithuania.

2.8 Individual Monitoring

General

The Radiation Act stipulates that the undertaking shall arrange monitoring of radiation exposure to exposed workers. Monitoring must be individual for category A workers. For practical reasons, monitoring in category B has often been arranged as individual monitoring as well. Category A includes such radiation work in which the annual effective dose is or may be higher than 6 mSv or the annual equivalent dose to the lens of the eye, the skin and hands or feet is or may be higher than 3/10 of the dose limits stipulated for these tissues or organs. Category B includes all other radiation work.

In accordance with section 34 of the Radiation Act (Amendment 1142/1998), STUK maintains a Dose Register of exposure to ionizing radiation of workers engaged in radiation work. The exposure data of individually monitored workers is registered in the Dose Register. The data to be registered is obtained from nuclear power plants and the Personal Dosimetry Service of STUK. Additionally, data is registered from Radiological Monitoring Documents of persons who have been working abroad and from reports of the Swedish Dose Register.

Individual doses caused by external radiation are measured with personal dosemeters. Results are reported in terms of the quantities deep dose $H_p(10)$ and surface dose $H_p(0.07)$, which are approximations of the effective dose and the equivalent dose to the skin. If the deep dose or surface dose is high the conditions leading to the exposure are determined and the effective dose or the equivalent dose to the skin will be estimated. The minimum registered dose (recording level) for the deep dose for nuclear power plant workers is 0.1 mSv/month and for other workers either 0.1 mSv/month or 0.3 mSv/3 months depending on

the monitoring period. Respectively, the recording level for the surface dose is 2 mSv/month or 6 mSv/3 months.

Individual doses caused by internal radiation are determined from samples of excreta or whole-body activity measurements. The effective dose of the worker is calculated from the measured activity and registered in the Dose Register.

Workers going to the Member States of the Community to work in Category A radiation work need a Radiation Passbook. A Radiological Monitoring Document (extract from the Dose Register) given by STUK together with a Certificate supplied by the medical practitioner responsible for the medical surveillance of the worker constitute the Radiation Passbook. The Radiological Monitoring Document is presented to the foreign undertaking, who enters in it the data on the duration of the radiation work, exposure to radiation during the work and the results of the worker's medical surveillance, if any. After the radiation work abroad has ended, the Document is returned to STUK which enters in the Dose Register the data recorded in the Document.

Individual monitoring in 2000

In 2000, individual monitoring covered 10 846 workers. About 46% of the employment relationships of the workers belong to category A and 41% to category B. Category has not been reported in 13% of the relationships.

Table *XX* presents the number of workers in various occupational categories. The number of workplaces having individual monitoring was 1171. The number of workers whose doses exceeded the recording level was 2976 (27%). The sum of the doses (total dose) recorded in the Dose Register was 6.5 Sv, of which nuclear power plant workers (Finnish workers in Finnish and foreign nuclear power plants and foreign workers in Finnish nuclear power plants) accounted for 4.4 Sv (68%) (Table *XXI*). Table *XXII* presents the number of monitored workers in 2000 in selected occupational groups and the total and mean doses in these groups.

The total dose of the workers in Finnish nuclear power plants was 4.0 Sv. The dose of outside workers (workers of contractors) was 3.3 Sv and that of power company operatives 0.7 Sv. The number of power plant own workers being monitored was 869, of whom 474 received doses exceeding the recording level. The number of outside workers being monitored was about 1960, of whom about 1310 received doses exceeding the recording level. The number of nuclear power plant workers who were exposed to internal radiation and whose doses exceeded the recording level (0.1 mSv) was 9. The sum of the internal doses was 1.2 mSv.

In 2000, no worker received a dose exceeding 50 mSv, the annual dose limit on the effective dose. In the period of 1996–2000, no worker received a dose exceeding 100 mSv, the dose limit for a 5-year period.

The highest deep dose measured in 2000 was 46 mSv. This dose was measured from dosemeters of a radiologist working in a hospital. The annual dose limit of the effective dose, however, was not exceeded, due to appropriate protective measures. The highest effective dose during the 5-year period of 1996–2000 was 93 mSv. The person in question was engaged in cleaning in a nuclear power plant.

In 2000, STUK issued 58 Radiological Monitoring Documents from the Dose Register.

Table XX. *Number of monitored workers in various occupational categories by specific dose ranges in 2000.*

Dose range (mSv)	Occupational category and number of workers					
	Healthcare	**Veterinary**	**Industry**	**Research**	**Nuclear energy**	**All**[*)]
< 0.3	4820	256	889	1218	1390[**)]	8480
0.3– < 0.5	162	10	33	8	237	432
0.5– < 5.0	424	21	105	24	1016	1566
5.0– < 10.0	38	5	4	3	195	246
10.0– < 20.0	29	0	1	2	77	111
≥ 20.0	11	0	0	0	0	11
Total	**5484**	**292**	**1032**	**1255**	**2915**	**10 846**

[*)] Since some workers were involved in more than one category, the number given in this column is not necessarily the same as the sum of the numbers in other columns in the same row.
[**)] 1050 workers received less than 0.1 mSv.

Table XXI. *Total doses received in various occupational categories in 2000.*

Occupational category	Total dose (Sv)
Healthcare	1.74
Veterinary	0.07
Industry	0.22
Research	0.10
Nuclear energy	4.40
Total	**6.53**

Table XXII. *Data on some occupational groups in 2000.*

Group	Number of monitored workers	Total dose (Sv)	Mean dose (mSv)		Highest dose (mSv)
			Workers whose doses exceed recording level[*)]	All monitored workers	
Radiologists	594	0.61	2.4	1.0	46.2
Interventional radiologists	25	0.18	8.0	7.4	41,7
Cardiologists	114	0.44	4.9	3.9	24.4
Surgeons	222	0.05	1.6	0.2	13.5
X-ray assistants	2475	0.20	0.7	0.1	6.0
Industrial radiographers	380	0.11	0.8	0.3	4.8
Researchers	941	0.04	1.5	0.0	8.6
Nuclear power plant workers					
• mechanical work	758	1,25	2.2	1.7	17.1
• material testing	233	0.49	2.5	2.1	14.8
• operational personnel	218	0.13	1.0	0.6	4.6
• cleaning	215	0.55	3.6	2.5	18.0
• insulation work	96	0.49	5.8	5.1	18.4
• radiation protection	75	0.24	3.5	3.5	14.2

*) The recording level for nuclear power plant workers was 0.1 mSv/month and for other workers either 0.3 mSv/3 months or 0.1 mSv/month depending on the monitoring period.

Individual monitoring during 10-year period in 1991–2000

Individual doses have been monitored and registered for over 30 years. The main purpose of centralized regulative control carried out by STUK is to ensure the safety of workers and workplaces.

Tables *XXIII-XXIV* present summaries of the numbers and doses of monitored workers in various occupational categories during 1991–2000[*)]. The category of nuclear energy includes workers at Finnish nuclear power plants.

*) The data presented in Tables *XXIII-XXIV* and *XXV* can differ slightly from that reported earlier, because some data were reported in the Dose Register after publication of the Annual Reports. Radiation work codes have also been completed and verified, when necessary.

Table XXIII. *Number of monitored workers in various occupational categories during 1991–2000.*

Year	Category and number of workers					
	Healthcare	**Veterinary**	**Industry**	**Research**	**Nuclear energy**	**All**
1991	6155	165	1124	1340	2147[*)]	10 824
1992	5970	199	1076	1433	3377	11 901
1993	5556	217	1010	1398	2902	10 957
1994	5384	233	1080	1457	3062	11 093
1995	5381	294	1188	1470	2555	10 775
1996	5523	271	1209	1516	3306	11 675
1997	5594	272	1234	1499	3138	11 673
1998	5542	293	1201	1409	3346	11 650
1999	5425	278	1125	1378	2403	10 502
2000	5484	292	1032	1255	2826	10 757

[*)] Only the number of workers whose doses have exceeded the recording level. Since 1992, data of nuclear power plant workers whose doses have been smaller than the recording level have also been recorded in the Dose Register.

Table XXIV. *Total doses of monitored workers in various occupational categories during 1991–2000.*

Year	Category and total dose (Sv)					
	Heathcare	**Veterinary**	**Industry**	**Research**	**Nuclear energy**	**All**
1991	1.16	0.07	0.13	0.21	3.08	4.65
1992	1.23	0.05	0.14	0.24	5.69	7.35
1993	1.35	0.05	0.18	0.21	3.79	5.58
1994	1.82	0.05	0.17	0.20	4.74	6.98
1995	2.02	0.06	0.18	0.14	2.24	4.64
1996	2.08	0.07	0.18	0.14	4.32	6.79
1997	2.08	0.05	0.23	0.11	2.81	5.28
1998	2.17	0.07	0.22	0.10	4.14	6.70
1999	1.71	0.04	0.15	0.07	2.30	4.27
2000	1.74	0.07	0.22	0.10	3.99	6.12
Total	**17.36**	**0.58**	**1.80**	**1.52**	**37.10**	**58.36**

Changes in individual monitoring

Changes in individual monitoring over the last 10 years are as follows:

- In early 1992, the new dose limits entered into force, and regulatory control of occupational exposure to natural radiation was initiated. The changes were due to a wide reform in radiation legislation, in which the new recommendations of the ICRP (International Commission on Radiological Protection) were effected.
- In 1993, the Personal Dosimetry Service of STUK began switching from the use of film dosemeters to thermoluminescent dosemeters. Old film dosemeters were definitively laid aside during 1995. As the result of the change, the accuracy of individual dosimetry was improved.
- Since early 1996, dosemeters have been calibrated in terms of the quantities deep dose $H_p(10)$ and surface dose $H_p(0.07)$ recommended by the ICRP (more precisely, personal dose equivalents at depths of 10 mm and 0.07 mm in tissue). These quantities yield better approximations of the effective dose and the dose equivalent to the skin than previous quantities of measurement. Previously, film dosemeters were calibrated in terms of the quantity dose equivalent. Doses corresponding to the effective dose and the dose equivalent to the skin were called the whole-body dose and the skin dose. The skin dose meant the dose equivalent from low-energy X-rays and beta radiation on the surface of the skin.
- In 1995, a Radiation Passbook was introduced when Finland joined the Community. This matter was enacted in the Amendment of the Radiation Decree (1598/1994), which is based on the Council Directive on the operational protection of outside workers exposed to the risk of ionizing radiation during their activities in controlled areas (90/641/Euratom).
- In 1998, the data systems of the Dose Register were revised. Concurrently, a separate data system independent from the Dose Register was created in the Personal Dosimetry Service. The recording level was changed to be dependent on the measurement period (e.g. 0.1 mSv/month or 0.3 mSv/3 months for the quantity deep dose).
- In 1999, the category of radiation work was first recorded in the Dose Register. Categorization was enacted in the Amendment of the Radiation Act (1142/1998) and the Amendment of the Radiation Decree (1143/1998). These Amendments resulted from the Council Directive in 1996 on the radiation protection of workers and the general public (96/29/Euratom). The measurement periods of individual monitoring were changed to 4 weeks in Category A and 12 weeks in Category B. The measurement period in nuclear power plants is 1 month, irrespective of the category.
- In 2000, the Personal Dosimetry Service of STUK was accredited in accordance with requirements of the standards SFS-EN 45001 and ISO/IEC Guide 25. The accreditation was granted by the FINAS (Finnish Accreditation Service).

Risk of cancer

According to ICRP*) estimation, the theoretical risk of a fatal cancer caused by radiation for adult workers is 4% per 1 Sv of effective dose. The risk is double if all cancers (including nonfatal) are also included.

The effective dose stands for the total health detriment when human organs and tissues are subject to radiation exposure. In radiation work, the effective dose of a worker can be estimated from the deep dose measured by an individual dosemeter. In practice, the deep dose gives a good approximation of the worker's effective dose. Exceptions to this are X-ray examinations in which the doses of the medical staff are measured by dosemeters worn above lead aprons, giving good protection to the body. Consequently, the deep doses of workers exposed to X-rays in health-

*) 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. International Commission on Radiological Protection (ICRP), 1991.

care and veterinary use of radiation are 10–60 times higher than their effective doses.

Table *XXV* presents a summary of the occupational radiation exposures of the individually monitored workers in 1991–2000 and an estimation of the number of radiation-induced fatal cancers (see footnote on page 30). In healthcare, workers exposed to X-rays are separated from other workers because their doses, as mentioned above, are not good approximations of the effective doses. The sum of the effective doses of workers exposed to X-rays in healthcare and veterinary use is estimated by dividing the sum of the deep doses by 30.

During the last 10 years, about 27 000 workers have been individually monitored. The estimate of the sum of their effective doses is 42.6 Sv. Theoretically, this exposure counts for about 2 fatal cancers. These cancers cannot be distinguished from cancers caused by other reasons. Annually, about 20% of all deaths in Finland are caused by cancer.

Table XXV. *Number of fatal cancers in various occupational categories during 1991–2000, estimated from the sum of the effective doses of individually monitored workers.*

Occupational category	**Number of workers**	**Sum of effective doses (Sv)**	**Theoretical number of fatal cancers**
Healthcare			
• workers exposed to X-rays	8466	0.52	0.021
• others	2082	1.65	0.066
Veterinary			
• workers exposed to X-rays	589	0.02	0.001
• others	19	0.01	0.000
Industry	2376	1.80	0.072
Research	3966	1.52	0.061
Nuclear energy	9418	37.10	1.484
Total	**26 916**	**42.62**	**1.705**

3 USE OF NON-IONIZING RADIATION

3.1 Regulatory Activities

The Decree on the Regulation of Non-Ionizing Radiation (1306/1993) forms the basis for the regulation of equipment emitting non-ionizing radiation and the use of such equipment. According to this Decree, it is the responsibility of STUK to assess the safety of various appliances that emit non-ionizing radiation and that may expose the general public in particular but also certain occupational groups to high intensities of non-ionizing radiation. Examples of such appliances include sunbeds, high-energy lasers used in public entertainment, high-frequency heaters, microwave dryers and mobile phone base stations.

In 1998, STUK proposed that the Ministry of Social Affairs and Health renew the Order on the Upper Limits of Exposure to Non-Ionizing Radiation. Further action regarding this Order was performed in 2000, because the Ministry of Commerce and Industry and the power transmission companies were not satisfied with the proposal. According to the Council Recommendation (1999/519/EC), the proposal was rewritten to be more like a guide. The Council Recommendation concerns limitation of exposure of the general public to electromagnetic fields.

In 2000, the number of inspections and radiation measurements performed for regulatory purposes was 14 for equipment emitting UV radiation and 3 for equipment emitting electromagnetic radiation. Market control for sunbeds was intensified by the inspection of 20 sunbeds. In addition, 7 statements were given.

In 2000, STUK investigated 2 abnormal occurrences in the use of non-ionizing radiation. One was associated with the use of sunbeds and the other with UV phototherapy. In both cases skin defects had been caused by excessive doses of UV radiation (see section 7).

3.2 Research Activities

Development of systems for the irradiation of animals and cell cultures

The objective of the CEMFEC project, partly financed by the Community, is to develop for the University of Kuopio an *in vivo* exposure device for rats, operated at 900 MHz, in which a large number of test animals can be exposed at the same time so that each animal can move freely in its cage and the whole-body SAR of the animals is accurately known. As an outcome of the study, exposure chambers (9 in all) will be constructed of 2 round plates with diameters of 1.5 m and separated from each other by a distance of about 15 cm. During 2000, planning of the equipment was completed. The prototype is under construction, and other necessary equipment has been provided; however, the project has been delayed about 6 months because it proved to be much more difficult than expected.

In the COST bis project financed by TEKES (National Technology Agency), a new type of cell exposure chamber, operated at 900 MHz, was completed and delivered to the University of Kuopio. The chamber is mounted horizontally outside an incubator. With the aid of effective temperature control it is possible to regulate the temperature of cells, despite the presence of microwave absorption, to be as close as possible to the preset temperature (37 ^{o}C). The SAR level of cell cultures in the chamber was measured. The performance of the chamber was as anticipated.

New antennas and measurement methods for 3rd-generation cellular systems

In the NAMS project (financed by TEKES), the goal of STUK is to develop the accuracy of SAR tests of mobile phones. During 2000, the following results were obtained in the project:

- calibration equipment for SAR probes operating at 20–450 MHz was planned
- SAR calibrations were expanded to include frequencies of 2.0 and 2.45 GHz
- in 2 interlaboratory comparisons it was found that the SAR testing equipment developed by STUK measures the SAR very precisely in a planar phantom, but results with large errors are obtained in a phantom simulating the anatomical shape of the head.

The study of EMC and safety of multimedia communication terminals

In the ASTE project ordered by the ESA (European Space Agency), radiation safety and radiation safety tests of satellite multimedia antennas are studied. During 2000, a literature review was performed on safety standards of frequencies over 10 GHz, and research was initiated based on another literature review on biological effects of microwave radiation in this frequency range. A scanning system for the measurement probe was planned for power density tests at 10 GHz, and for permitivity measurements the optimal composition (ethanol-water mixture) of the solution needed for the SAR test phantom was found.

Other research work

- The article dealing with broadband and pulsed magnetic fields was corrected according to the comments received from the reviewers. The article was published in the journal Health Physics.
- STUK helped the University of Kuopio to conduct a study concerning the occupational safety aspects of antitheft alarm systems.
- STUK helped the Tampere Regional Institute of Occupational Health to study the exposure to broadband magnetic fields that appear in the metal industry.
- The manuscript for the study (carried out in cooperation with municipal health authorities) on the use of sunbeds was completed. The results of the study will be published in the STUK A Reports Series.
- The report of magnetic examinations and their safety in medicine was published in the report series of the National Agency for Medicines.

3.3 Other Activities

Information and education

Some public circles showed increasing concern, especially about the health risks of the electromagnetic fields in mobile phones and their base stations. In 2000, STUK experts advised on these health risks by phone and internet. The press, radio and TV were given several interviews on the subject. Three articles were written in daily newspapers and the ALARA magazine.

A service was initiated on the STUK website in which the UV index from the previous day to the observation time can be seen during the period from May to September. The index is based on the precisely determined irradiance of UV radiation measured on the roof of the STUK premises in Roihupelto.

Also in 2000:

- STUK published a guide for microwave dryers in the series STUK Bulletins. The guide contains the safety requirements for the use of microwave dryers.
- Experts from STUK participated in a Community workshop in which safety questions of magnetic fields caused by antitheft alarm systems and similar equipment were addressed. Preparation of a document was begun for guidance of the Community and its Member States in these matters.
- STUK arranged 2 training courses concerning the health effects of UV radiation and one course concerning the effects of electromagnetic fields.

International cooperation

In 2000, a representative of STUK participated in the following international cooperative meetings and measurement campaigns:

- A meeting of the standing committee SC 3 of the ICNIRP (International Commission on Non-Ionizing Radiation Protection) in San Antonio, where the opinion of the ICNIRP concerning broadband and pulsed magnetic fields was prepared in its final form. This opinion was based on the proposal made earlier by STUK.
- Comparison of radiometers to detect solar UV radiation arranged by the Nordic Ozone Working Group. The results of STUK were well within the estimated uncertainties compared with the average results.
- The meeting of the Nordic Ozone Working Group in Copenhagen.
- The EU Thematic Network meeting in Borås dealing with UV radiation measurements.
- An international workshop on the UV index in Munich.
- A meeting of the working group WG 16 of the IEC committee TC 61 in Hamburg, where the standard IEC 335-2-27 dealing with the radiation safety of sunbeds was renewed.
- Meetings of the committee SCC 28 and its subcommittees SC 3 and SC 4 of the American standardization organization IEEE in Munich.
- The annual meeting of the Bioelectromagnetics Society (BEMS) in Munich.

Other

A plan was made for the National Agency for Medicines to determine the changeability of lamps used in UV therapy equipment and sunbeds.

4 NATURAL RADIATION

In accordance with section 45 of the Radiation Act, whoever uses earth, rock or other raw materials existing in nature for industrial purposes is required to investigate the radiation exposure caused by this practice if it is found, or if there is reason to suspect, that the practice constitutes a radiation practice. The same applies to an employer if it is discovered or if there is reason to suspect that the radiation exposure originating from natural radiation and occurring in the employer´s working facilities or other workplace causes or is liable to cause a health hazard.

4.1 Radon

Radon in workplaces

Indoor radon is the most significant source of exposure to natural radiation in workplaces. STUK monitors radon in mines, excavation sites and other underground workplaces, as well as in other workplaces where high radon concentrations occur. The action level for radon in workplaces with regular working hours is 400 $Bq \cdot m^{-3}$.

In 2000, radon concentrations were measured in the premises of 59 employers. In addition, check measurements were made in 22 workplaces in which previous measurements indicated that the action level may have been exceeded. In late 2000, the monitoring register of STUK contained 71 enterprises that had been ordered to reduce the radon concentrations or to measure the actual concentrations during working hours by using an instrument that monitors radon concentrations continuously. The concentrations during working hours were measured in 35 workplaces (in the premises of 13 enterprises) in which long-term measurements had shown the concentrations to exceed the action level. Orders to reduce the concentrations were given to 10 of the workplaces. In 8 workplaces further investigations are needed, while in 17 workplaces no further measures were necessary because measurements showed that the concentrations during working hours were below the action level.

A total of 4 underground mines and one underground excavation site were inspected for the presence of radon. The radon concentrations were less than 400 $Bq \cdot m^{-3}$ in all cases except for the Mullikkoräme mine. The reason for the high concentrations observed is the intense flow of radon-rich water from the bedrock into the mine. The concentrations in different working areas ranged from 1000 to 2000 $Bq \cdot m^{-3}$. The mine was closed in summer 2000.

Approval of radon-measuring instruments

Instruments and methods used for determining radon exposures of workers must be approved by STUK. An instrument can only be approved if it is properly calibrated. The organizations (enterprise, community, institute or corresponding) whose instruments have been approved for determining the radon exposures of workers and who have valid calibrations for their instruments are presented in Table *XXVI*. The Table also shows the dates by which the instruments must be recalibrated if the approvals are to remain valid.

Table XXVI. *Organizations whose instruments have been approved for determining radon exposures of workers.*

Organization	**Instrument**	**Calibration valid until**	**Notes**
Gammadata Mätteknik i Uppsala AB/Gammadata Finland Oy, Helsinki	Alpha track detector	1 Jul 2001	A detector with which long-time averages of radon concentrations can be determined. The detector is not suitable for registering variations in radon concentrations over time. The detector is also approved for radon measurements in homes.
City of Äänekoski	Radon-Box 10	31 Aug 2001	An instrument with which short-time averages (7 days) of radon concentrations can be determined. The instrument is not suitable for registering variations in radon concentrations over time.
• Tampere Polytechnic • Municipality of Janakkala • Kymenlaakso Polytechnic • Rovaniemi Polytechnic • City of Lahti • Turku Polytechnic	• Pylon AB-5 and Alpha Guard • Ionization chamber • Pylon AB-5 • Pylon AB-5 • Pylon AB-5 • Pylon AB-5	• 27 Jul 2002 31 Dec 2002 • 31 Dec 2000 • 13 Apr 2001 • 31 Dec 2001 • 4 Apr 2002 • 20 Jun 2001	Continuously monitoring instruments with which variations in radon concentrations over time can be registered. The instruments are suitable for measuring radon concentrations during working hours.

4.2 Other Sources of Natural Radiation

For regulatory purposes, STUK measured the activities of a total of 28 samples of peat ash. The results did not lead to any further measures concerning the handling or mounding of the ash.

STUK monitors the radioactivity of drinking water in accordance with ST Guide 12.3. The Guide is applicable to waterworks that provide water for more than 50 persons or for more than 10 households. In 2000, inspection protocols were drawn up regarding the radioactivity of 29 different water samples. In 4 cases, the responsible parties were requested to reduce the activity concentrations in the water. In most of these cases, the action level for radioactivity was exceeded due to radon. Measures for reducing the concentrations were requested to be taken within one year.

The Institute for Mineral Technology of the Technical Research Centre of Finland (VTT) in Outokumpu was inspected for assessing occupational exposures related to experimental enrichment of ore from Gabon that contained natural uranium and thorium. Exposures of the workers were so low that no special measures were needed to restrict them.

5 METROLOGY

In accordance with section 23 of the Radiation Act (Amendment 1334/1994), STUK shall maintain metrological standards for ensuring the reliability of radiation measurements. Radiation in this case means both ionizing and non-ionizing radiation. The aim of metrology activities is to ensure adequate accuracy and international comparability of radiation measurements. The national standards are traceable to the definitions of measurement quantities either directly or through internationally accepted standards.

5.1 Ionizing Radiation

Standards, traceability and measurement uncertainties

The standards used by STUK for measuring ionizing radiation are ionization chambers or radiation sources. Mostly, they are secondary standards calibrated against primary standards by BIPM (International Bureau of Weights and Measures) or the national standards laboratories in the UK or Germany (NPL or PTB, respectively). The traceability chains of the standards for ionizing radiation are shown in Figure 5. National standards are maintained for air kerma, absorbed dose, dose equivalent, reference air kerma rate (for brachytherapy) and surface activity. The measuring uncertainties (expanded uncertainty with a coverage factor of 2) for these quantities are: air kerma 1–3%, absorbed dose 3–5%, dose equivalent 2–10%, reference air kerma rate 2–3% and surface activity about 10%.

For the maintenance of standards and calibration of instruments, the following equipment and radiation sources are available at STUK:

- Gamma irradiation devices: ^{60}Co and ^{137}Cs gamma sources (different activities)
- X-ray equipment: 160-kV and 320-kV units
- Beta-ray secondary standard: ^{147}Pm, ^{204}Tl and ^{90}Sr/^{90}Y beta sources
- Neutron secondary standard: Am/Be neutron sources
- Wide-area alpha and beta sources: ^{90}Sr/^{90}Y, ^{36}Cl and ^{14}C beta sources, ^{241}Am alpha source.

Maintenance of standards

In 2000, the national standards for ionizing radiation were maintained as before. In regular quality-control measurements (constancy tests), no deviation higher than the acceptance level was observed. In the annual dose measurement audit at the therapy level organized by the IAEA and using TLD, deviations of the STUK results from the IAEA reference value were less than 1% and did not exceed the acceptance level of the IAEA (3.5%). Table *XXVII* shows the summary of STUK results in the IAEA dose audits for 1990–2000.

Documentation of the quality manual for the standard dosimetry activities of STUK was improved, aiming at accreditation of the most routine calibration services in 2001.

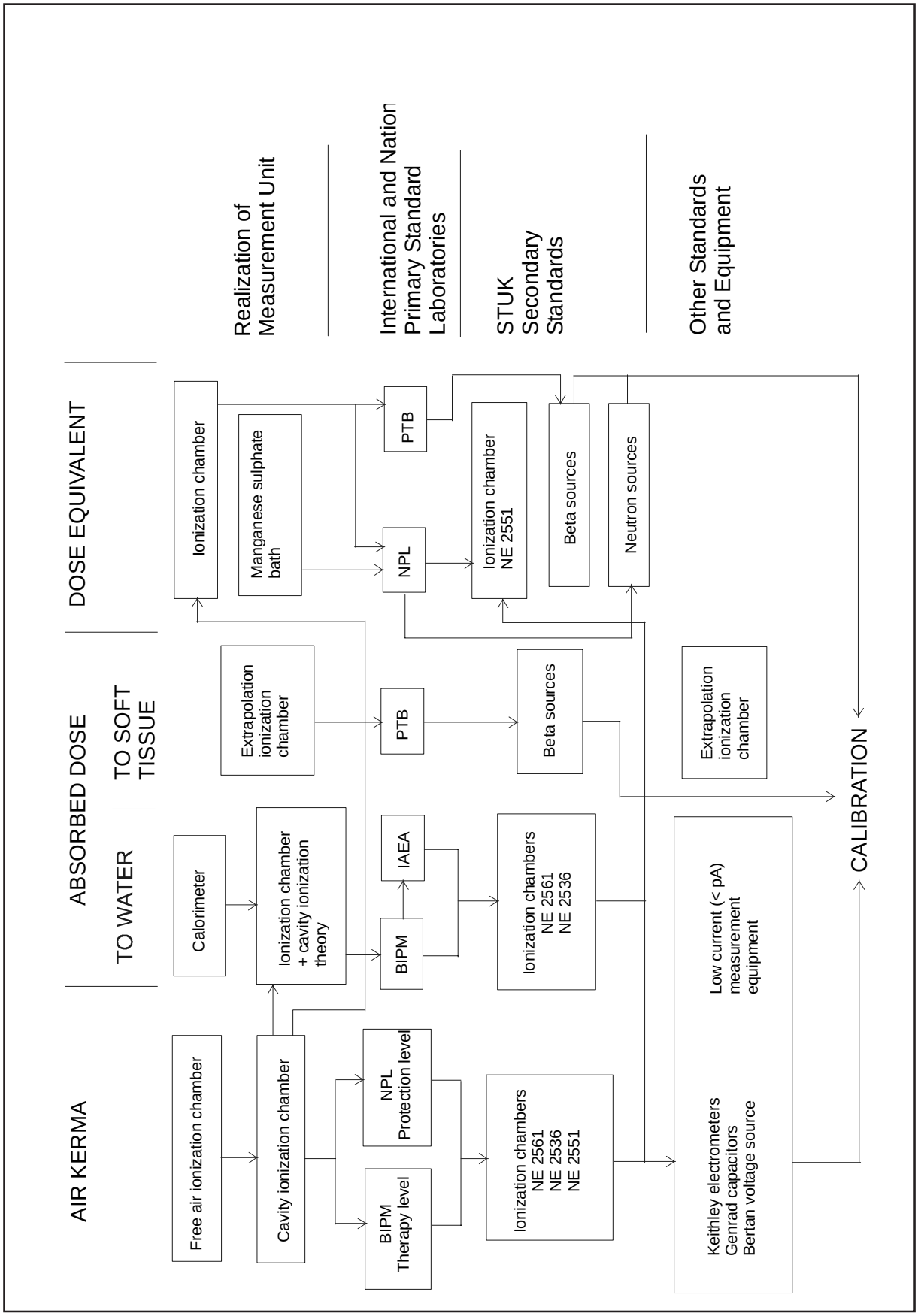

Figure 5. *Traceability chains of the STUK standards for ionizing radiation.*

Table XXVII. *Deviations of the STUK results from the IAEA reference value. TLD dose audits at the therapy level in 1990–2000.*

Year	**Deviation (%)**	
	TLD dose audit, ^{60}Co gamma beam	**TLD dose audit, high-energy X-ray beam**
1990	– 0.2	
1991	– 0.4	
1992	– 0.2	– 0.5 (18 MV)
1993	– 0.0	+ 0.9 (15 MV)
1994	+ 1.4	+ 3.2 (10 MV)
1995	+ 0.2	– 1.7 (6 MV)
1996	– 1.7	– 0.7 (18 MV)
1997	– 0.5	
1998	+ 0.8	– 0.2 (6 MV)
1999	+ 0.6	+ 0.3 (4 MV)
		+ 0.3 (15 MV)
		+ 0.4 (18 MV)
		+ 1.2 (25 MV)
2000	- 0.1	– 1.1 (4 MV)

Calibration and testing of ionizing radiation meters

A total of 145 ionizing radiation meters were calibrated or tested. About half of the calibrations and tests were ordered by customers other than STUK. A total of 65 batches of individual dosemeters and 46 batches of other samples were irradiated. A total of 65 calibration certificates, 13 inspection certificates for civil defence dosemeters, 23 irradiation certificates and 8 test reports were issued.

Development of standards and calibration equipment

A new computer program was prepared and used for the calculation of air kerma rates of the multisource irradiator (Revolver) used in protection level calibrations. A new calibration method, based on the use of the monitor chamber and a constant calibration distance, was introduced for the calibration of dosemeters in diagnostic radiology. For the calibration of brachytherapy sources, a new method based on using a well-type chamber was introduced on a trial basis. The electric installations of the 2nd measuring carriage were started.

National and international cooperation

With regard to ionizing radiation quantities, STUK is a member of the international network of Secondary Standard Dosimetry Laboratories (SSDLs) jointly sponsored by the IAEA and the WHO (World Health Organization). STUK participates in the annual dose measurement audits of the network (see section on Maintenance of standards, page 39). In 2000, a representative of STUK served as the contact person for ionizing radiation and radioactivity for EUROMET (European Collaboration on Measurement Standards). In addition, a representative of STUK participates as a member in the National Board for Metrology and in the Eurolab-Finland Organization.

A representative of STUK participates in an ICRU Report Committee which prepares ICRU recommendations on patient dosimetry for diagnostic radiology, and in WG 3 of IEC Committee SC 62C dealing with the standardizaton of radiation-measuring instruments. Furthermore, a representative of STUK serves as the Finnish contact person for IEC Committee SC 62C and ISO Committee TC 85. Comments for a total of 15 draft standards were given in 2000.

In 2000, a STUK expert visited Minsk in Belarus by invitation of the IAEA for evaluation of the quality system of the local SSDL laboratory. Invited by the Swedish accreditation body (SWEDAC), a STUK expert also visited the calibration laboratory of the Swedish Radiation Protection Institute (SSI) to participate in the external audit of the laboratory.

The Radiation Metrology Laboratory of STUK has been responsible for practical exercises in training courses organized by STUK for customs officers. In 2000, 3 such courses were organized, 2 of them for customs officers in the Baltic countries and 1 for Finnish customs officers.

5.2 Non-Ionizing Radiation

STUK maintains measurement standards for non-ionizing radiation necessary for its regulatory role. National-level standards are maintained for spectral UV irradiance as well as for intense electric and magnetic fields in the frequency ranges of greatest importance for safety.

The standards for the spectral UV irradiance (1-kW quartz-halogen lamps) were traced in 1995 to the primary standard of the National Standards Laboratory of the United States (NIST) directly and to the primary standard of PTB in 1995 via an accredited laboratory (the lamp supplier) and also in 1998 to the primary standard of the Metrology Research Institute of the HUT (Helsinki University of Technology) (Figure 6). The latter calibration was checked in 1999.

In 2000, STUK participated in a study concerning improvement in the accuracy of solar UV measurements. This study is part of a wide-ranging Community project coordinated by the NPL and belonging to an SMT programme (standards, measurements and tests). The goal of the STUK sub-project is to develop, in cooperation with the

Metrology Research Institute of the HUT, a field calibrator (a transfer standard) for spectroradiometers monitoring the Sun and based on quartz-halogen lamps. This calibrator will be stabilized with semiconductor detectors and calibrated against a cryogenic absolute radiometer using the filter radiometers of the HUT as transfer standards. In 2000, the first prototype of the calibrator was devised and constructed. Laboratory and field tests showed that the performance of the calibrator was as planned.

For intense electric and magnetic fields, precise calibration chains do not exist because there are no sufficiently precise transfer standards. STUK employs calibration equipment of its own design (TEM chambers and calibrated antennas in a radio anechoic chamber). The accuracy of the equipment was compared with the national standards of Germany, the Netherlands, Sweden and the UK (PTB, VSL, SP, NPL, respectively) in 1992. The traceability chains of the standards for electric and magnetic fields are presented in Figure 7.

In 2000, STUK calibrated 18 meters for UV measurements and 13 meters for measurement of electromagnetic fields. In addition, 1 safety evaluation was made.

In 2000, STUK participated in a comparison organized by the EUROMET for the calibration of low-frequency magnetic fields. Deviation of the STUK result from the reference value was within the evaluated uncertainty.

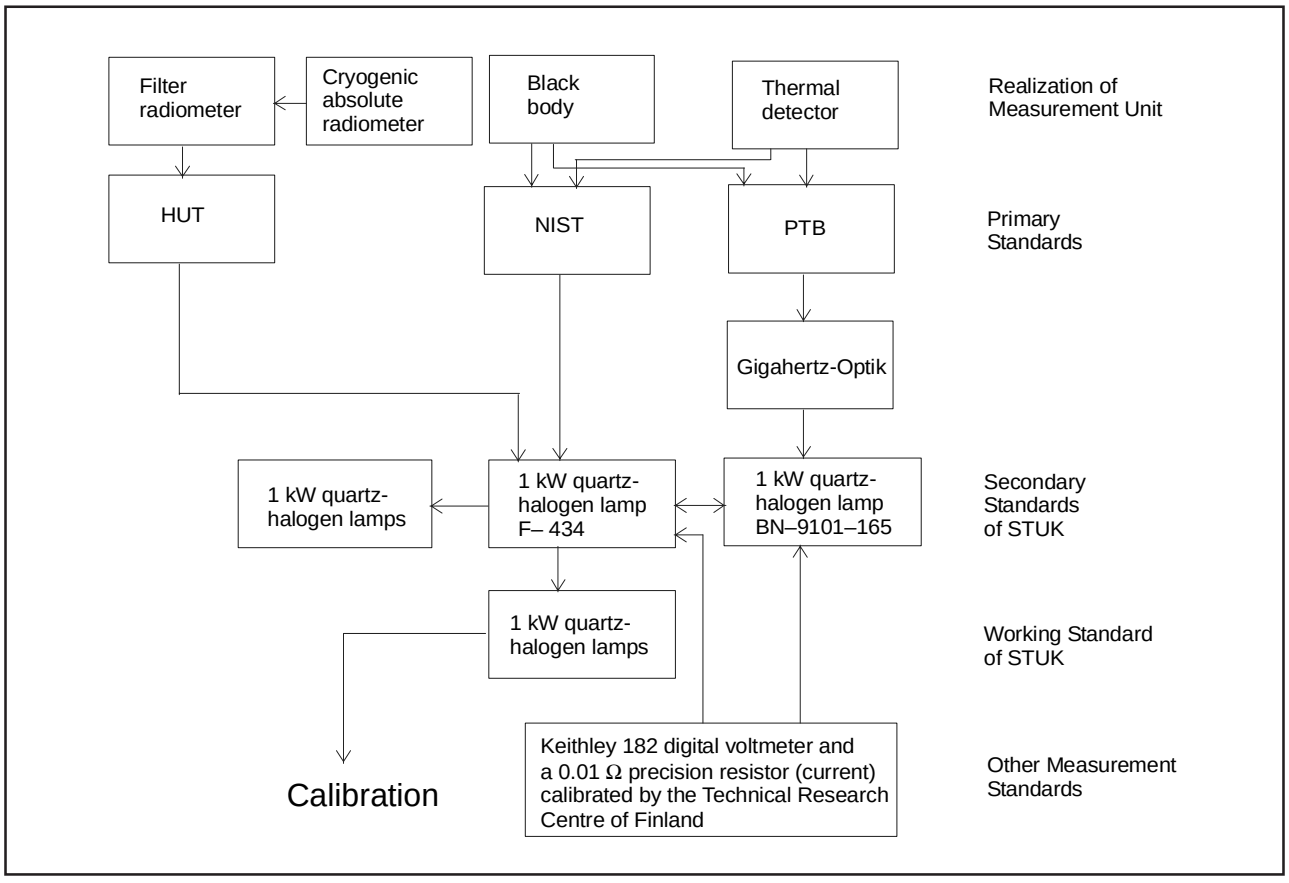

Figure 6. *Traceability chains of the STUK standards for UV radiation.*

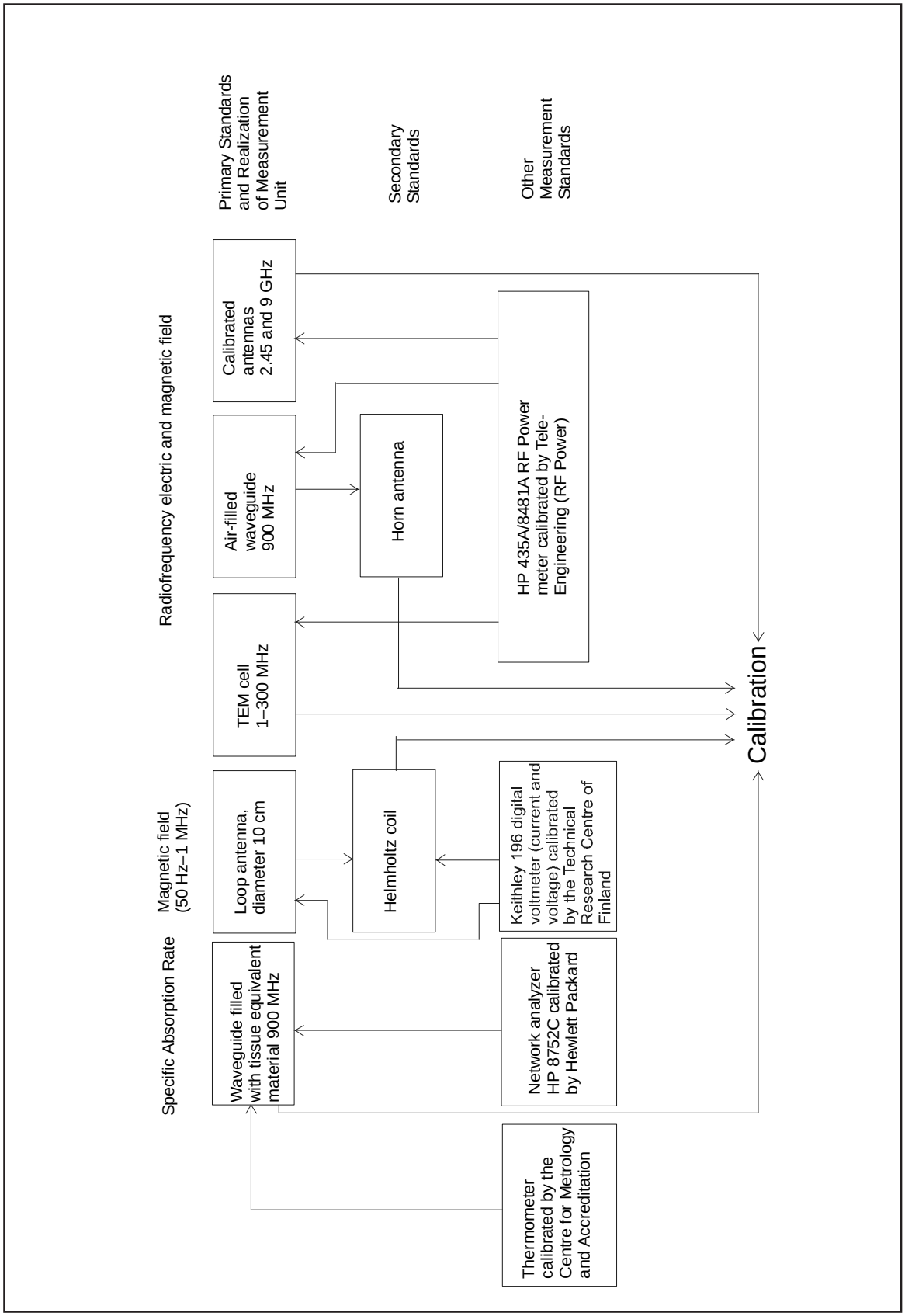

Figure 7. *Traceability chains of the STUK standards for electric and magnetic fields.*

6 REGULATIONS

6.1 Radiation Act, Radiation Decree and ST Guides

Provisions concerning the use of ionizing radiation and other radiation practices were stipulated in the Radiation Act (592/1991) and the Radiation Decree (1512/1991) and in regulations issued by virtue of these. Adherence to the Radiation Act and the regulations issued by virtue of it is controlled by STUK, which also issues instructions on the medical uses of radiation under supervision of the Ministry of Social Affairs and Health. Radiation practices and their safety are also subject to the Community legislation and international agreements concerning radiation safety signed by Finland.

The Radiation Act and the Radiation Decree were last amended in 1998 when the Amendment to the Radiation Act (1142/1998) and the Amendment to the Radiation Decree (1143/1998) were passed. In addition, the Ministry of Social Affairs and Health in 2000 issued a Decree on the Medical Use of Radiation (423/2000). STUK participated in the preparation of all these regulations.

In accordance with section 70 of the Radiation Act, STUK issues general instructions on how to attain the level of safety defined in the Act. These instructions are given in ST Guides which particularize the provisions given in radiation legislation and account for Community legislation and international recommendations. Examples of good manufacturing practice related to the safety of radiation practices and guidance on safe working procedures are given in informative STUK Bulletins.

ST Guides are evaluated and renewed according to international development so that the safety requirements given in the Guides are always up-to-date. The contents of a particular Guide and the conditions for keeping it in force are checked when 5 years at most have elapsed after enforcement of the Guide. If there is no need to change the contents, the Guide can be in force for 10 years at most.

ST Guides are prepared in STUK by working groups whose members can, when necessary, also include outside persons. Internal comments from STUK experts are obtained to every draft guide and drafts are also sent for comments to outside experts and interest groups. When necessary, the opinion of the Advisory Committee on Radiation Safety can also be requested.

Before enforcement, the Commission will be notified of an ST Guide in case it contains requirements following from the implementation of Directives, or in case earlier such requirements are changed. According to the Decision of the Council of State (802/1999), the Ministry of Trade and Industry will also be notified of a Guide before its enforcement, in case it contains such technical requirements on products that may have implications for foreign trade. The Ministry notifies the Commission and the World Trade Organization (WTO) of the Guide.

If there is no need to notify the Commission, information exchange systems of the Community or the WTO of the Draft Guide, the Guide will be enforced by the Director General of STUK. If the Commission, the Community and the WTO have been notified of the Draft, then there will be a waiting period (stand still) of 3 months during which the Guide may not be printed. During this time, the Commission and the Members States of the Community or the WTO can give their comments on the Draft. After this, the comments are incorporated and the Guide will be enforced.

In 2000, 4 new ST Guides were published:

- ST 5.4 Trade in Radiation Sources (in Finnish)
- ST 7.1 Monitoring of Radiation Exposure
- ST 7.4 Registration of Radiation Doses
- ST 12.1 Radiation Safety in Practices Causing Exposure to Natural Radiation (in Finnish).

6.2 Provisions of the Community

Community provisions concerning radiation practices have been laid down by article 30 of the Treaty establishing the European Atomic Energy Community (EURATOM). Council Regulations are binding in their entirety and are directly applicable in all Member States. The provisions given in the Directives, however, shall be implemented into national legislation. STUK is the competent authority related to the radiation Directives (BSS and MED) of the Euratom Treaty .

Council Regulation (Euratom) No 1493/93 pertains to shipments of radioactive substances between Member States. Pursuant to this Regulation, STUK, as the competent authority, sends a declaration to the consignor of a sealed source or radioactive waste in another Member State stating that the consignee in Finland fulfils the national provisions implementing the BSS Directive. In addition, STUK receives and processes declarations quarterly sent by consignors concerning all shipments of sealed sources or radioactive waste to Finland.

Community provisions concerning the radiation safety of workers and the general public are covered by Directive 96/29/Euratom (BSS) whose provisions on medical exposures have been supplemented by Directive 97/43/Euratom (MED). The provisions of these 2 Directives have been implemented into Finnish legislation by Amendments to the Radiation Act and the Radiation Decree and by Decree of the Ministry of Social Affairs and Health, all mentioned in section 6.1. ST Guides 7.1, 7.4 and 12.1 published in 2000 included the last set of provisions implementing the BSS Directive. The tasks assigned to STUK by Decree of the Ministry of Social Affairs and Health related to the implementation of the MED Directive are still under preparation.

Training programmes for exposed workers, approved medical practitioners, other medical practitioners, dentists, assistants and qualified experts are communicated to the Commission (Commission Recommendation 91/444/Euratom). ST Guides concerning the radiation safety training of exposed workers and definition of the contents of radiation safety training for various worker groups in the radiation user´s organization are under preparation (Article 33 of the Euratom Treaty).

Community provisions concerning products are given in Directives laid down by the Treaty establishing the European Economic Community (EC). The essential safety provisions of medical devices – also radiation appliances – have been laid down in the Medical Devices Directive 93/42/EEC. This Directive has been implemented into Finnish legislation by the Medical Devices Act and Decree (1505/1994 and 1506/1994). Regulatory control of the safety, manufacturing and marketing of medical devices is the responsibility of the National Agency for Medicines.

Contribution to the preparation of Community provisions

STUK contributes to the preparation of Community provisions and international recommendations by participating in working groups preparing these provisions and recommendations. On the Community level, work in the so-called article 31 Expert Group (and its subgroups) is of special importance. Together with the Commission, the Group prepares proposals to the Council for Community provisions concerning radiation practices. A representative of STUK also participates, as necessary and on request, as a representative of Finland in work of the Atomic Questions Group of the Council (reading by state officials) whenever questions concerning radiation safety and especially new related provisions are on the agenda. As appropriate, STUK also participates in meetings of the IAEA, preparing recommendations for radiation practices and regulatory control.

Standardization work related to Community provisions

A common Community practice is that the acceptability of products is indicated by CE-marking. Fulfilment of the essential provisions of a Directive is indicated, in practice, by demonstrating that a product fills the provisions of the harmonized standards (EN standards) related to this Directive. A list of harmonized standards is published in the Official Journal of the European Communities. Concerning radiation appliances, the harmonized standards are the CENELEC (European Committee for Electrotechnical Standardization) standards that are, in practice, prepared by the IEC.

Regulatory control performed by STUK concerns radiation safety in the use of appliances. STUK cannot issue provisions concerning the fabrication, construction and functioning of an appliance. Since it has been interpreted that more stringent safety requirements cannot be required during the use of an appliance than when accepting the appliance on the market, the IEC standards essentially also set constraints on safety requirements for use. STUK participates in the IEC and the CENELEC standardization work by participating in the working groups, giving comments to the draft standards and by stating its position to the Finnish voting behaviour when the standards are accepted.

7 ABNORMAL OCCURRENCES

In accordance with section 17 of the Radiation Decree, STUK shall be notified of any abnormal occurrences connected with the use of radiation that are substantially detrimental to safety at the location where the radiation is used or in its environs. In addition, STUK shall be notified of any radiation source that has disappeared, been stolen, lost or otherwise ceased to be in the possession of the licence holder. Notification to STUK shall also be made of any abnormal observation or data with an essential bearing on the radiation safety of workers or the environment.

In 2000, no serious accidents occurred involving radiation in Finland, nor any incidents that could possibly have led to radiation accidents. However, STUK investigated 13 incidents that were or were suspected to be abnormal in the use of radiation. Six of these incidents were related to the use of radiation in industry, 1 to the medical use of radiation, 2 to the use of non-ionizing radiation, 2 to the nationwide radiation monitoring network and 2 to consumer goods.

Table *XXVIII* is a summary of the abnormal incidents investigated in 2000. The Table also summarizes the causes and consequences of the incidents and the measures taken. In describing and publishing these case histories, STUK wishes to inform the users of radiation of the potential hazards in the use of radiation, as well as of the appropriate preventive measures for precluding such cases in the future.

Table XXVIII. *Abnormal incidents involving radiation in 2000.*

Case	Cause	Measures taken
Case 1. Five workers were exposed to radiation from a level gauge (700-MBq ^{60}Co-source) during maintenance work at a foundry. The maximum effective dose estimated on the basis of working hours was about 0.2 mSv.	The workers entered the foundry's oven without first closing the beam shutter of the level gauge.	Working instructions at the foundry were amended so that entering the oven is only allowed with a written work permission indicating that the shutter is closed.
Case 2. Two workers were slightly exposed during work in the vicinity of a level gauge (370-MBq ^{137}Cs-source). The effective doses of the workers were 0.1 mSv at the most.	The level gauge had been dismantled from the side of a burner unit and the shutter was left open so that the workers were working in the radiation beam. Investigations showed that the owner of the device did not have a safety licence in accordance with section 16 of the Radiation Act and the importer of the device had not ensured that the consignee of the device had a licence as stipulated in section 28 of the Radiation Act.	STUK asked the police to investigate whether the case involved violations of the provisions of the Radiation Act.

Case	Cause	Measures taken
Cases 3 and 4. Two industrial measuring devices, both containing radiation sources (1.2-GBq and 2.3-GBq ^{137}Cs sources) were found in scrap yards. A worker handling the larger source was slightly exposed.	The manner in which the devices had found their way into the scrap was not discovered because their owner remained unknown. STUK's register had not been notified of the devices, and no safety licences had been applied for them. The importer of the devices has been bankrupted.	The sources are stored for the time being at a temporary storage of STUK. STUK issued a press release concerning the larger source and the case was brought to publicity by the media. In addition, STUK sent a letter to scrap yards advising them to focus attention on possible radioactive sources among scrap. The scrap yards were also sent a poster “Watch out for radioactive scrap”.
Case 5. A nonradiating ore-sorting device carrying a radiation warning sign was found in a scrap yard.	The owner of the device had removed the radioactive sources from the device before delivering it to the scrap yard, but had not removed the radiation warning signs and the sign plate of the device.	STUK reminded the owner about neglecting the removal of the signs.

Case	Cause	Measures taken
Case 6. A level gauge containing a radioactive source (240-MBq ^{60}Co source) was lost during dismantling of an industrial silo. The device was sought at the industrial establishment in question and at the scrap yard of the company responsible for the dismantling work, but it was not found.	It had not been properly overseen that the device was delivered, after its detachment, to the storage site for radioactive sources at the establishment.	The written instructions for handling sources at the establishment were supplemented and the responsibilities of the personnel were specified. STUK issued a press release about the case, and it received media publicity.
Cases 7 and 8. At 2 emergency response centres an automatic radiation monitor triggered an alarm although the dose rate of the external radiation was normal.	1. The alarm was triggered due to the presence of a fireman who had been subject to a nuclear medicine examination. 2. The alarm was triggered by industrial radiographic work carried out in the neighbourhood.	1. No further measures were taken. 2. To avoid unnecessary alarms, STUK sent a letter to industrial radiography undertakings giving instructions on radiographic work in the neighbourhood of emergency response centres.

Case	Cause	Measures taken
Case 9. A customer received second-degree burns on her face in a beauty salon sunbed.	The lamps of the sunbed had been changed and, thus, the filtering glasses of the facial tanner had been removed and not yet been replaced. The equipment was not properly supervised resulting in inadvertent use by a customer.	STUK ordered the beauty salon to take proper measures to prevent equipment which is out of order from being inadvertently used by customers.
Case 10. A patient being treated with UV light in a health centre received burns all over his body.	The timer of the treatment equipment did not work. According to the information obtained, in the particular health centre patients take UV treatments with no supervision following only the advice given to them.	Further actions to be taken are being considered by the National Agency for Medicines.

Case	Cause	Measures taken
Case 11. Watches made in Hong Kong whose watch-straps had metal parts containing radioactive cobalt (^{60}Co) were found in France. The IAEA notified the case to all Member States.	The reason for contamination of the metal parts of the watch-straps has not been determined.	According to an investigation made by the Consumer Agency, no watches of the type in question were sold in Finland.
Case 12. A telephone dealer was selling covers of mobile phones with a radiation hazard marking on them.	The variety of goods sold by the dealer involved many covers, specially meant to attract young people.	There is no reason for using radiation hazard markings when no hazard is present. The case was carried over to be studied by the Consumer Agency.

Case	Cause	Measures taken
Case 13. An incident in X-ray diagnostics made STUK suspect violation of the principle of justification stipulated by section 2 in the Radiation Act.	A newspaper published an article of a rock musician together with an X-ray photograph of the skull of the musician.	STUK asked the Radiation Safety Officer of the laboratory that had taken the X-ray photograph to give his opinion on the justification for the photograph. The Safety Officer said that the Staff Medical Officer had referred the musician for the X-ray.

APPENDIX 1

Legislation governing radiation practices in Finland

Statute	Statute no.
Radiation Safety	
Radiation Act	592/1991
• Amendment	1102/1992
• Amendment	1334/1994
• Amendment	594/1995
• Amendment	490/1997
• Amendment	1142/1998
Decree on the Enforcement of the Amendment to the Radiation Act	1597/1994
Radiation Decree	1512/1991
• Amendment	1598/1994
• Amendment	1143/1998
Ministry of Social Affairs and Health Decree on the Medical Use of Radiation	423/2000
Decree on the Regulation of Non-Ionizing Radiation	1306/1993
Ministry of Social Affairs and Health Order on the Upper Limits of Exposure to Non-Ionizing Radiation	1474/1991
Ministry of Social Affairs and Health Order on the Upper Limits for Radon Concentration in Places of Residence	944/1992
Regulatory Organization	
Act on the Radiation and Nuclear Safety Authority (STUK)	1069/1983
• Amendment	1106/1987
Decree on the Radiation and Nuclear Safety Authority (STUK)	618/1997
Charges	
Ministry of Social Affairs and Health Order on the Liability to and the Basis of Charges for Services Rendered by the Radiation and Nuclear Safety Authority (STUK)	580/1993
Transportation	
Legislation for transportation of dangerous materials also covers transportation of radioactive substances	

APPENDIX 2

Regulations, Decisions, Directives and Recommendations concerning radiation safety in the Community

Council Directive 90/641/Euratom of 4 December 1990 on the operational protection of outside workers exposed to the risk of ionizing radiation during their activities in controlled areas

Commission Recommendation of 26 July 1991 on the application of the third and fourth paragraphs of Article 33 of the Euratom Treaty (91/444/Euratom)

Council Directive 92/3/Euratom of 3 February 1992 on the supervision and control of shipments of radioactive waste between Member States and into and out of the Community

Council Regulation (Euratom) No 1493/93 of 8 June 1993 on shipments of radioactive substances between Member States

93/552/Euratom: Commission Decision of 1 October 1993 establishing the standard document for the supervision and control of shipments of radioactive waste referred to in Council Directive 92/3/Euratom

Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation

Council Directive 97/43/Euratom of 30 June 1997 on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure, and repealing Directive 84/466/Euratom

Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz–300 GHz) (1999/519/EC)

APPENDIX 3

Training organizations authorized to carry out qualification interviews for radiation safety officers and for other users of radiation, as of 1 February 2001.

Date of approval	Organization	Qualification in radiation safety
Medical use of radiation		
20 Dec 1991	Stadia, Helsinki Polytechnic, Health Care and Social Service	Responsible Operator
21 Jan 1992	Stadia, Helsinki Polytechnic, Health Care and Social Service	Dental X-ray, Responsible Operator
5 May 1997	University of Helsinki, Faculty of Veterinary Medicine	Veterinary X-ray
29 Feb 1996	University of Helsinki, Physics Department	General Use of Radiation
15 Apr 1993	University of Helsinki, Department of Diagnostic Radiology	X-ray Diagnostics and Use of Radioactive Substances (Specialty in Radiology, examination)
10 Apr 1992	ARCADA, Nyland Swedish Polytechnic, School of Health Care	Dental X-ray, Responsible Operator
20 Dec 1991	Northern Savo Polytechnic, School of Health Care	Responsible Operator
1 Jun 1992	Northern Savo Polytechnic, School of Health Care	Dental X-ray, Responsible Operator
10 May 1993	University of Kuopio, Department of Clinical Radiology	X-ray Diagnostics and Use of Radioactive Substances (Specialty in Radiology, examination)
6 Oct 1992	University of Kuopio, Training and Development Centre	Use of Radiation (excluding General Use)
20 Dec 1991	Oulu Polytechnic, School of Health Care	Responsible Operator
25 Nov 1994	Oulu Polytechnic, School of Health Care	Dental X-ray, Responsible Operator
25 Apr 1997	Oulu Polytechnic, School of Health Care	Surgical X-ray, Responsible Operator
20 Dec 1991	University of Oulu, Faculty of Medicine	X-ray Diagnostics and Use of Radioactive Substances
27 May 1993	University of Oulu, Faculty of Medicine	X-ray Diagnostics and Use of Radioactive Substances (Specialty in Radiology, examination)
20 Dec 1991	Educational and Training Board in Medical Physics	General Use of Radiation
3 Mar 1992	Board of Qualification for Hospital Chemists	Use of Radioactive Substances
29 Feb 1996	Tampere Technical University, Ragnar Granit Institute	General Use of Radiation
20 Dec 1991	Pirkanmaa Polytechnic, Health Care and Social Services	Responsible Operator
17 Aug 1993	University of Tampere, Faculty of Medicine	X-ray Diagnostics and Use of Radioactive Substances (Specialty in Radiology, examination)
20 Dec 1991	Turku Polytechnic, Health Care and Social Service	Responsible Operator
3 Aug 1992	Turku Polytechnic, Health Care and Social Service	Dental X-ray, Responsible Operator
26 Jan 1994	University of Turku, Faculty of Medicine	X-ray Diagnostics and Use of Radioactive Substances
8 Jun 1993	University of Turku, Faculty of Medicine	X-ray Diagnostics and Use of Radioactive Substances (Specialty in Radiology, examination)
20 Dec 1991	Vaasa Swedish Polytechnic, School of Health Care	Responsible Operator

APPENDIX 3 (CONTINUES)

Date of approval	Organization	Qualification in radiation safety
Use of radiation in industry, research, teaching and education; trade in and maintenance of radiation sources		
20 Dec 1991	AEL, Centre for Technical Training, NDT Technics	Industrial Radiography (Responsible Operator)
6 Apr 1993	Stadia, Helsinki Polytechnic	Trade in Radiation Sources, Maintenance of Radiation Sources
3 Apr 1992	University of Helsinki, Department of Physics	General Use of Radiation, Use of Unsealed Sources, Use of X-ray (excluding Industrial Radiography), Use of Radiation in Educational Demonstrations, Trade in Radiation Sources
26 Jan 1994	University of Helsinki, Lahti Research and Continuing Education Centre, Palmenia	General Use of Radiation, Trade in Radiation Sources
8 Apr 1992	University of Helsinki, Faculty of Forestry and Agriculture, Instrument Centre	Use of Sealed and Unsealed Sources
3 Apr 1992	University of Helsinki, Department of Radiochemistry	Use of Sealed and Unsealed Sources
26 Aug 1992	Jyväskylä Polytechnic	Industrial Radiography, Use of Sealed and Unsealed Sources, Trade in Radiation Sources, Maintenance of Radiation Sources
31 Jan 1995	University of Jyväskylä, Department of Physics	Trade in Radiation Sources, Use of Radiation Sources in Industry, Research, Teaching and Education
6 Oct 1992	University of Kuopio, Training and Development Centre	Use of Radiation (excluding General Use), Trade in Radiation Sources, Maintenance of Radiation Sources
12 Mar 1992	Lappeenranta University of Technology	General Use of Radiation, Use of X-ray, Use of Sealead and Unsealed Sources
4 Aug 1994	University of Oulu, Department of Physics	Trade in Radiation Sources, Use of Radiation Sources in Industry, Research, Teaching and Education
4 May 1992	University of Oulu, Department of Biochemistry	Use of Sealed and Unsealed Sources
15 May 1992	Northern Savo Nursing Care District	Trade in Radiation Sources, Maintenance of Radiation Sources
21 Jan 1992	POHTO, Institute for Management and Technological Training	Use of X-ray and Sealed Sources (excluding Industrial Radiography)
18 May 1992	Satakunta Polytechnic	Use of X-ray, Industrial Radiography, Use of Sealed Sources, Trade in Radiation Sources
21 Jan 1992	SPEK, Finnish National Rescue Association	Installation and Maintenance of Fire Detection Devices
14 Feb 1992	Tampere Polytechnic	Use of X-ray and Sealed Sources (excluding Industrial Radiography)
3 Aug 1992	Turku Polytechnic	General Use of Radiation, Industrial Radiography, Use of X-ray, Use of Sealed Sources, Trade in Radiation Sources, Maintenance of Radiation Sources
3 Aug 1992	University of Turku, Department of Physics	General Use of Radiation, Industrial Radiography, Use of X-ray, Use of Sealed Sources, Trade in Radiation Sources