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College on Medical Physics
(10 October - 4 November 1988)

Dosimetry in Diagnostic Imaging

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** These notes are intended for internal distribution only

ICRU REPORT 17

Radiation Dosimetry: X Rays Generated at Potentials of 5 to 150 kV

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INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS

4201 CONNECTICUT AVENUE, N.W.
WASHINGTON, D.C. 20008
U.S.A.

Radiation Dosimetry: X Rays Generated at Potentials of 5 to 150 kV

1. Relationships Between Radiation Quantities and Units

For energies below 150 keV the mean free path of a photon in water, or other material of low atomic number, is about 1000 times the range of an electron of the same energy. Thus charged particle equilibrium will be closely approached even in the absence of photon equilibrium.

Furthermore, at such energies, an electron slowing down in water loses less than 0.1 % of its total energy by bremsstrahlung production. Even in a material such as uranium, a 150 keV electron loses only 2.6 % of its energy by bremsstrahlung production when slowing to rest. For lower atomic number materials and lower energy electrons the bremsstrahlung losses will be still smaller.

In the presence of charged particle equilibrium and the absence of bremsstrahlung losses the kerma, K, is equal to the absorbed dose, D, in a volume element. For monoenergetic photons both quantities are then related to the energy fluence, Ψ, by the equations

$$D = K = \Psi \frac{\mu_K}{\rho} \qquad 1.1$$

where μ_K/ρ is the mass energy transfer coefficient. Further, in the absence of bremsstrahlung losses, μ_K/ρ is equal to μ_{en}/ρ, where μ_{en}/ρ is the mass energy absorption coefficient. Thus

$$D = K = \Psi \frac{\mu_K}{\rho} = \Psi \frac{\mu_{en}}{\rho} \qquad 1.2$$

When the radiation covers a range of energies, the quantity μ_{en}/ρ must be replaced by $\bar{\mu}_{en}/\rho$ where $\bar{\mu}_{en}/\rho$ is a mean value of μ_{en}/ρ weighted according to the spectral distribution of energy fluence with respect to energy.

Exposure, X, relates only to the special substance, air, and satisfies the relationship

$$X = \frac{e}{\bar{W}_{air}} \Psi \cdot \left(\frac{\mu_{en}}{\rho}\right)_{air} \qquad 1.3$$

or, introducing specific units, and taking $\bar{W}_{air} = 33.7$ eV (i.e. $\bar{W}_{air}/e = 33.7$ J/C)

$$\frac{X}{R} = 115 \frac{\Psi}{J \cdot m^{-2}} \cdot \frac{(\mu_{en}/\rho)_{air}}{m^2 \cdot kg^{-1}} \qquad 1.4$$

Again, if the radiation has a range of energies, a weighted mean value of $(\mu_{en}/\rho)_{air}$ must be used, as indicated earlier.

The conversion of a measured exposure to absorbed dose in a medium requires a knowledge of the ratio $(\bar{\mu}_{en}/\rho)_{med}/(\bar{\mu}_{en}/\rho)_{air}$. The conversion of absorbed dose in one medium to absorbed dose in another requires that the ratio of the weighted mean mass energy absorption coefficients be known. When either the Compton effect or the photoelectric effect contributes nearly all the energy absorption in both materials, this ratio is not critically dependent on the spectral distribution of energy fluence with respect to energy. When both processes are contributing significantly, the spectral distribution must be accurately known.

Energy fluence is considered in Section 2, its spectral distribution with respect to energy in Section 3, exposure in Section 4, absorbed dose in Section 5 and mass energy absorption coefficients in Section 6. Kerma is not discussed further in this report because of its very close approximation to absorbed dose in the energy range considered.

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of the present report refers to new work since the completion of Report 10b, including two additional approaches: (iv) spectrometry with gas proportional counters, and (v) lithium-drifted germanium detectors. The significance of less complete quality specifications will be considered in Section 3.2.

Spectra appearing in the literature are not always directly comparable due to the various forms in which they are given; thus, they may be expressed in terms of energy fluence rate against energy, photon fluence rate against energy, exposure rate against energy, exposure rate against wavelength, etc. Although photon fluence rate is readily converted to energy fluence rate by multiplying it by the corresponding photon energy, and exposure rate is converted to energy fluence rate by dividing it by $(\mu_{en}/\rho)_{air} \cdot e/\overline{W}$, special care is needed in converting distributions against wavelength into distributions against energy. An ordinate in a distribution against wavelength has to be multiplied by $d\lambda/d(h\nu)$ to convert it to the corresponding ordinate in a distribution against photon energy, and $d\lambda/d(h\nu)$ is proportional to $(h\nu)^{-2}$.

The derivation of approximate x-ray spectral distributions from attenuation data, if either time or facilities are not available for obtaining complete spectra, has been discussed by Greening (1963). Tables are given which simplify the procedure of representing an x-ray beam by three monoenergetic components when appropriate points on the transmission curve of the radiation in a suitable absorber are known. In another approach, three components are fitted graphically to the attenuation data. Such approaches have the merit of basing the spectral derivation on measurements of the actual beam concerned, as against employing published spectra for supposedly similar apparatus. Greening's tables have been designed for use with x rays generated over a range of potentials and filtrations, including 20 to 150 kV with aluminium absorbers.

For x rays generated at pulsating potentials of 45 to 105 kV and used in diagnostic radiology, Epp and Weiss (1966, 1967) have reported new experimental data for primary and scattered radiations. Using scintillation spectrometry techniques (1966) they have determined primary spectra in this energy range for continuous tube currents of 3 to 5 mA. These fluoroscopic conditions yielded spectra approximating those which would be obtained with the somewhat different generating potential waveforms of radiographic settings. *HVL*'s were computed from the spectra and were found to be in close agreement with direct ionization chamber determinations using the chamber designed by Garrett and Laughlin (1959), discussed in Section 4.3.3 and Figures 4.3 and 4.5.

Peaple and Burt (1969) have developed a transportable spectrometer and collimating system for the measurement of photon spectra. The pulse height distributions obtained with a sodium iodide crystal are converted to photon spectra using a method due to Scofield (1960), and the technique has been applied to a wide range of spectral distributions for x-ray machines operated under pulsating potentials up to 100 kV.

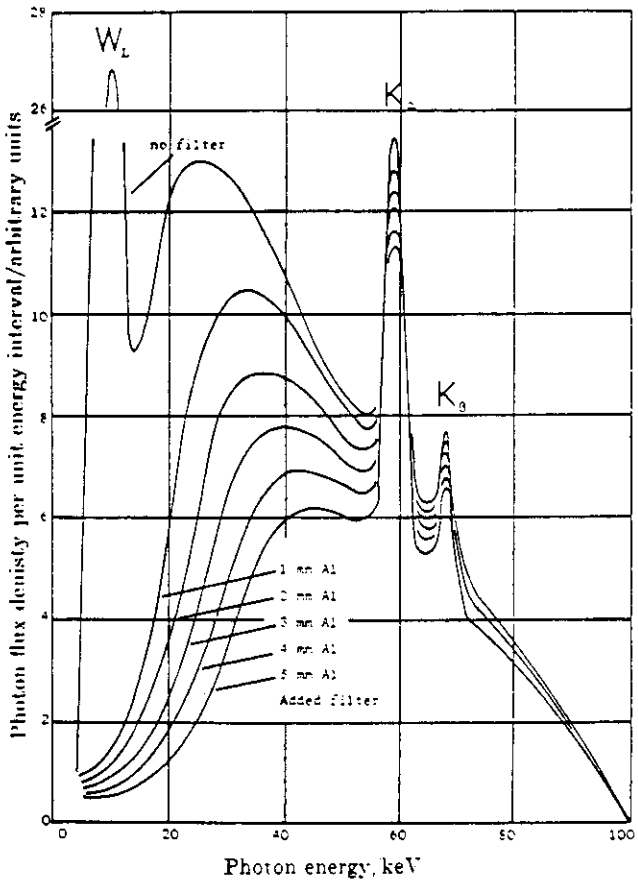

Fig. 3.1. Spectral distributions of x rays from a tube with 1 mm Be inherent filtration operated at 100 kV and with various filters (measured after passage through 2 m of air).
[Derived from Drexler and Perzl, 1968b]

Drexler and Perzl (1967, 196Sa,b) have employed lithium-drifted germanium detectors for spectral measurements. Figure 3.1 illustrates some of the results achieved. A catalogue has been prepared (Drexler and Gossrau, 1968) containing 87 spectra for tubes operated at potentials of 25 to 300 kV (62 of these below 150 kV), with a range of Al, Cu, Sn and Pb filtration.

Epp and Weiss (1967) gave results of measurements of spectral distributions of scattered radiations obtained by scintillation spectroscopy over the diagnostic range of 70 to 150 kV. Spectra were obtained at depths in water ranging from 2 to 10 cm for irradiated surface areas of 50 to 500 cm². Tables of values of spectral flux density expressed as a function of x-ray beam quality, beam area and depth in water were derived for combined scattered and primary radiations. Figure 3.2 illustrates

Hospital Physicists' Association

Diagnostic Radiology Topic Group

The Physics of Radiodiagnosis

(Second Edition – Revised 1976)

Topic Group Membership:

M. Davison	A. J. Stacey	J. Kennedy
G. A. Hay	G. Spiegler (*deceased*)	A. Robinson
B. E. Keane	G. Innes	B. L. Reece
R. T. Rogers	E. Shuttleworth	B. M. Moores
R. D. Moore	J. Law	M. Bullen
L. A. MacKenzie	A. Dixon-Brown	E. T. Henshaw (*Report Editor*)

PREFACE

This publication is the combination of four separate reports which were prepared by the Diagnostic Radiology Topic Group of the Hospital Physicists' Association during the period from 1969 until 1974.

It is not the intention that these reports should provide a comprehensive text of the physics of diagnostic radiology but rather that they should update the knowledge and application of physics to radiodiagnosis in the light of recent developments.

The members of the Topic Group during the time these reports were prepared and the combined edition was published were:

M. Davison	A. J. Stacey	E. T. Henshaw
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B. E. Keane	G. Innes	A. Robinson
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L. A. MacKenzie	A. Dixon-Brown	M. Bullen

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Mr. C. B. Clayton (Royal Victoria Infirmary, Newcastle-on-Tyne)

Mr. A. Parkinson (Peacocks Ltd., Newcastle-on-Tyne)

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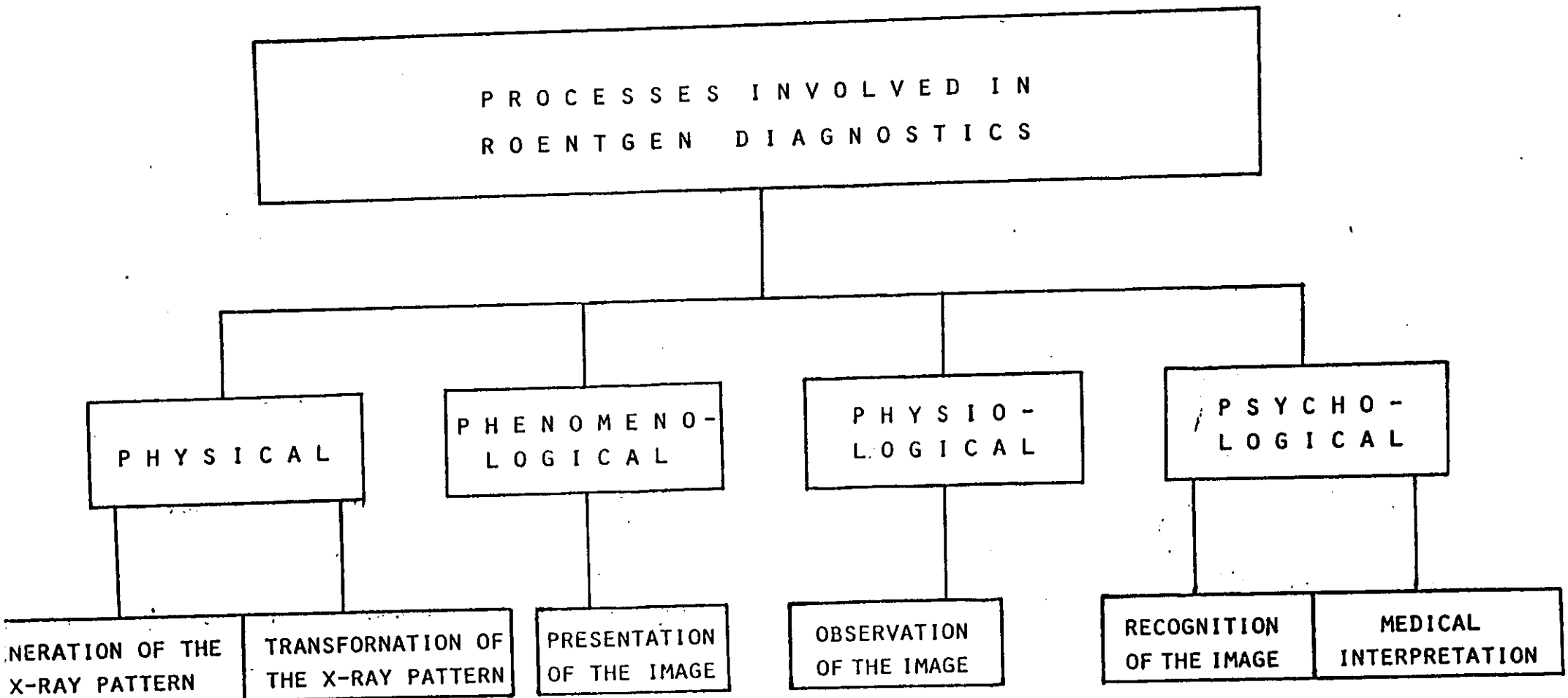
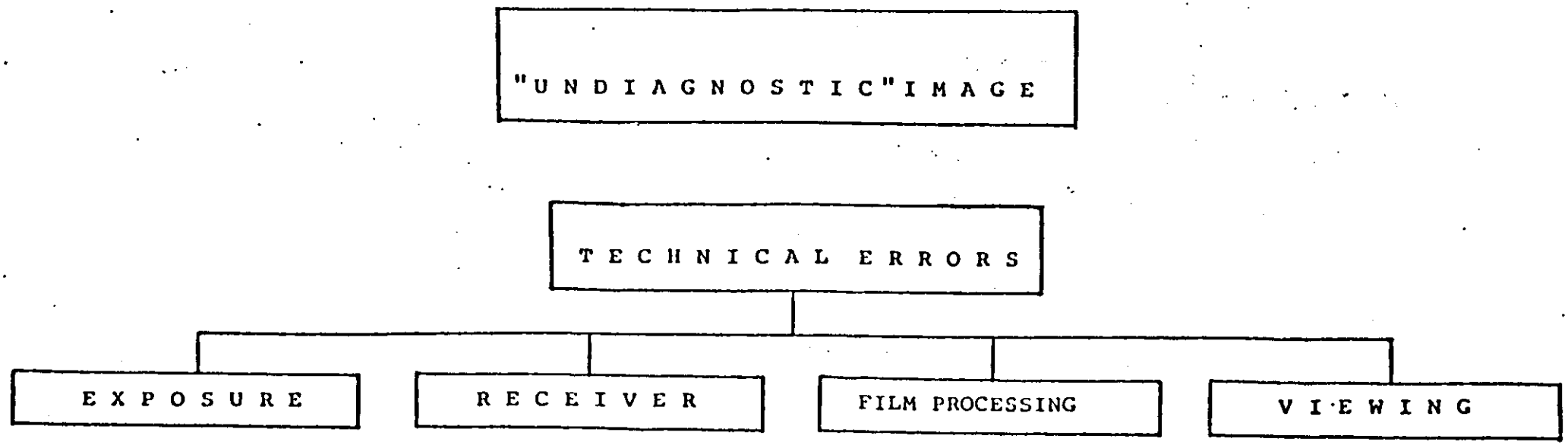
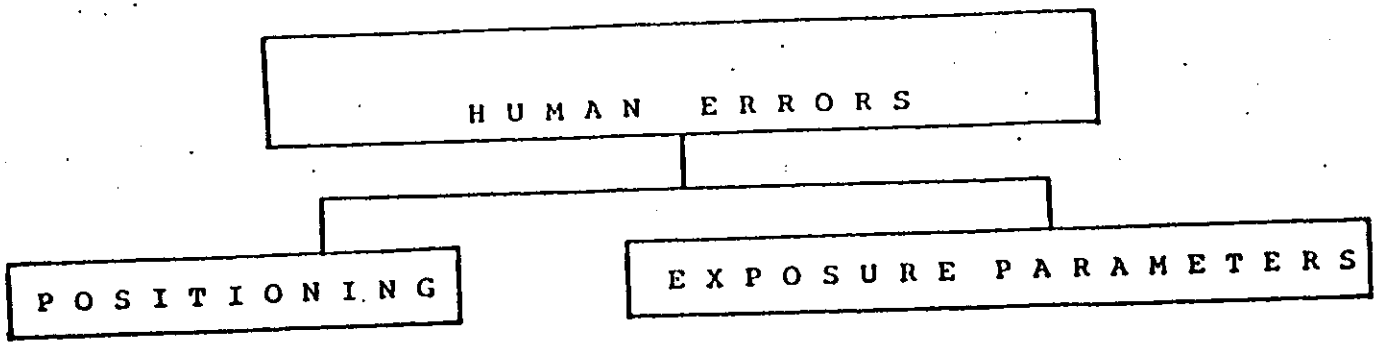

PROCESSES INVOLVED IN ROENTGEN DIAGNOSTICS
PHYSICAL
PHENOMENO-LOGICAL
PHYSIO-LOGICAL
PSYCHO-LOGICAL
NERATION OF THE X-RAY PATTERN
TRANSFORNATION OF THE X-RAY PATTERN
PRESENTATION OF THE IMAGE
OBSERVATION OF THE IMAGE
RECOGNITION OF THE IMAGE
MEDICAL INTERPRETATION


"UNDIAGNOSTIC"IMAGE
TECHNICAL ERRORS
EXPOSURE
RECEIVER
FILM PROCESSING
VIEWING
TUBE VOLTAGE
TUBE CURRENT
EXPOSURE TIME
AUTOMATIC EXPOSURE CONTROL
LIGHT FIELD / RADIATION FIELD
FILM SCREEN CONTACT
CONDITION OF SCREEN
CONDITION OF FILM
DEFECTIVE CASSETTES CASSETTES
DEVELOPER TEMPERATURE
DEVELOPER ACTIVITY
MECHANICAL DAMAGE OF FILMS
LIGHT INCIDENCE
INHOMOGENIOUSLY ILLUMINATED AREA
BLINDING
AMBIENT ILLUMINATION



CENTERING

PROJECTION

DISTANCE

FIELD SIZE

IMMOBILIZING

INADEQUATE POSITIONING
OF PROTECTIVE DEVICES

ANTI SCATTER GRID

MODE OF IMAGING

EXPOSURE FACTORS

(kV, mAs, s)

FOCAL SPOT SIZE

RECORDING MATERIAL
(SENSITIVITY, FORMAT)

4.10. Quality Assurance Programs

The purpose of quality assurance (Q.A.) programs in diagnostic radiology is to establish procedures for monitoring periodically or continuously the performance of radiological facilities with the aim of obtaining optimum diagnostic information at minimum cost and with minimum radiation dose to individual patients.

stimated worldwide diagnostic x-ray examinations and machines in 1987
(numbers in parentheses indicate per cent of total)

Level of health care	Population in millions	Diagnostic x-ray machines in thousands	Diagnostic examinations in millions	Approximate examinations per machine
I	1300 (26)	330 (76)	1040 (75)	3000
II	1750 (35)	88 (20)	260 (19)	3000
III	1220 (24)	15 (3)	61 (4)	4000
IV	730 (15)	4 (1)	22 (2)	5500
Total	5000 (100)	440 (100)	1380 (100)	

Diagnostic x-ray examinations in different countries

Level of health care	Population per physician	Country	Annual examinations per 1000 population	Population per x-ray machine	Year
I	less than 1000	Argentina		2800	1978-1982
		Canada	1016	3200	1980
		Finland	958	-	1984
		France	820	2700	1987
		Germany, Fed. Rep.	836	-	1978
		Italy	749	-	1983
		Japan	1314		1979
		Libyan Arab J.		8000	1977
		Netherlands	648		1980
		Norway	641		1983
		Spain	490	4400	1986
		Sweden	700		1977
		United Kingdom	496		1983
		United States	790	1800	1980
		USSR	958		1981
II	1000 - 2999	Bolivia	-	27000	1978-1982
		Brazil	179	13400	1982
		Chile	166	13000	1982
		China	259	16400	1980
		Colombia	211	14300	1978-1982
		Costa Rica	270	19200	1981
		Cuba	139	11000	1978-1982
		Dominican Republic	20	80000	1981
		Equador	36	-	1981
		Iran	180	-	1981
		Mexico	70	15000	1980
		Nicaragua	57	-	1981
		Paraguay	-	41000	1978-1982
		Peru	-	12000	1978-1982
		Turkey	80	-	1978
		Uruguay	-	8800	1978-1982
		Venezuela	-	10000	1978-1982
III	3000 - 9999	Kenya	36	100000	1970
		India	23	65000	1977
		Liberia	80	70000	1977
		Singapore	-	60000	1977
		Sri Lanka	21	-	1979
		Sudan, Rep. of		150000	1984
		Thailand	34	-	1077
IV	more than 10 000	Ethiopia		300000	1977
		Ghana	22	100000	1977
		Ivory Coast	40	190000	1977
		Nigeria	25	90000	1977

Annual frequency of diagnostic nuclear medicine examinations
(per 1000 population)

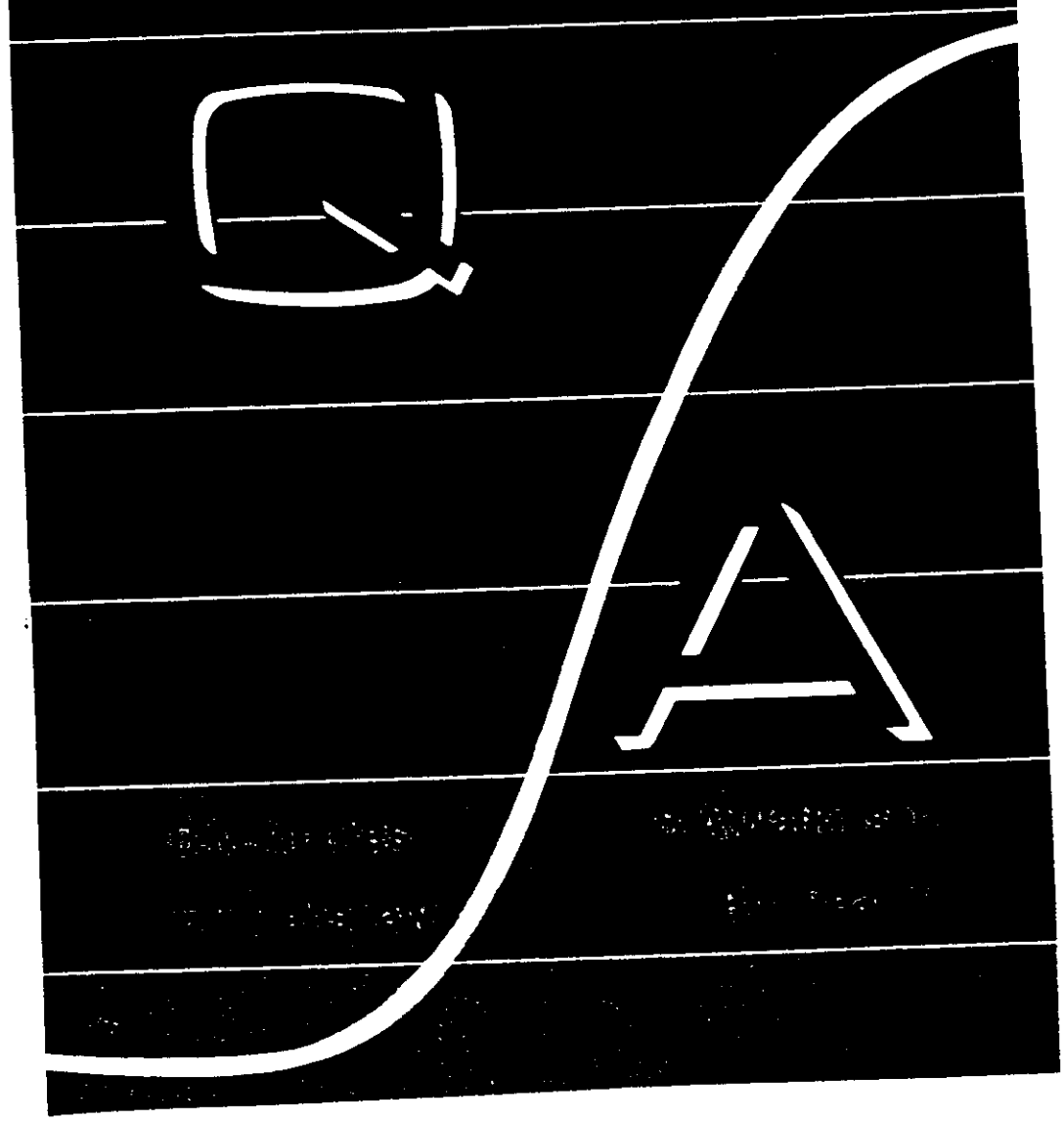
Country	1970-1972	1973-1975	1977-1979	1980-1982
Australia	4			8
Austria			18	
Bulgaria				13
Burma	0.1		0.2	
Canada				49
China				0.6
Cuba	0.8		0.8	
Denmark		8	14	14 a/
Finland				18
France				9
Japan			5	
Poland				2
Sweden	8	12	15	15
United Kingdom				7
United States b/	16	11	29	31
USSR				4

a/ 1985 value.
b/ Earlier value: 4 (1966).

Procedures to reduce collective dose equivalent in diagnostic x-ray examinations

Area	Procedure	Reduction factor
All types	Elimination of medically unnecessary procedures	1.2
	Introduction of quality assurance programme (general)	2.0
Radiography	Decrease in rejected films through QA programme	1.1
	Increase of peak kilovoltage	1.5
	Beam collimation	0.5-3.0
	Use of rare earth screens	2-4
	Increase of filtration	1.7
	Rare earth filtration	2-4
	Change from photofluography to chest radiography	4-10
	Use of carbon fibre materials	2
	Replacement of CaWO4 screens with spot film technique	4
	Entrance exposure guidelines	1.5
	Gonadal shielding	2-10 (to gonads)
Pelvimetry	Use of CT topogram	5-10
Fluoroscopy	Acoustic signal related to dose rate	1.3
	Use of 105 mm camera	4-5
	Radiologist technique	2-10
	Variable aperature iris on TV camera	3
	Change from chest fluoroscopy to radiography	20
	High and low dose switching	1.5
Digital Radiography	Decrease in contrast resolution	2-3
	Use of pulsed system	2
Computed tomography (head)	Gantry angulation to exclude eye from primary beam	2-4 (to eye)
Mammography	Intensifying screens	2-5
	Optimal compression	1.3-1.5
	Filtration	3

Practical Guide to Quality Assurance in Medical Imaging



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Criteria and Methods for Quality Assurance in Medical X-ray Diagnosis

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Dosimetry in Diagnostic Radiology
to ascertain:

-- Adeqate Image Quality
-- at reasonable cost and
-- at A L A R A doses

Table I Exposure parameters considered optimal for good radiographic techniques and simulated in the calculations. a.p.=anteroposterior; p.a.=posteroanterior; FFD=focus to film distance

	Voltage (KVP)		FFD(cm)	
	Range	Typical value	Range	Typical value
Thorax p.a.	110-150	125	150-200	180
Thorax lateral	110-150	125	150-200	180
Skull p.a.	65- 85	70	90-150	115
Skull a.p.	65- 85	70	90-150	115
Skull lateral	65- 85	70	90-150	115
Lumbar spine + sacrum a.p.	75- 90	80	90-120	115
Lumbar spine + sacrum lat.	90-100	90	90-120	115
Pelvis a.p.	70- 90	75	90-120	115
Bladder a.p.	65- 90	75	90-120	115

Table II Organ doses for the female phantom normalised to dose at the image receptor in Sv/Sv for a thorax posteroanterior examination. FFD=focus to film distance

VOLTAGE (KVP)	110	110	150	150	125
FFD (cm)	150	200	150	200	180
Breast	7.87	8.00	7.31	6.75	7.20
Colon asc.+transv.	0.26	0.31	0.30	0.30	0.29
Lense of eye	0.23	0.16	0.18	0.17	0.17
Lungs	32.08	31.89	26.74	23.72	26.60
Red bone marrow	7.22	7.50	6.41	5.99	6.42
Skeleton	17.62	18.40	13.65	12.82	14.49
Thyroid	3.52	3.99	3.71	3.70	3.59
Uterus	0.04	0.05	0.06	0.06	0.05
Total body	7.55	7.89	6.21	5.81	6.42
Surface entrance	70.50	66.11	53.29	42.04	49.66

1. Measurements inside the beam (image formation)

1.1 Radiation Quality:

- tube voltage
- voltage divider
- spectrometry
- attenuation
- HVL

1.2 Radiation Quantity

Output:

- specific K E R M A / rate
- free in air at patient side
- surface entrance
- surface exit
- image receptor
- K E R M A - area product
- special / CT etc

2. Measurements outside the beam

(Radiation Protection)

2.1 worker

-- ambient dose equivalent

-- personal dose equivalent

-- effective dose equivalent

2.2 patient

-- organ dose equivalent

-- risk weighted dose equivalent

The effective dose equivalent H_E

is the summation

of the product

of the weighting factor w_T

and related

mean dose equivalent H_T

for all the relevant

organs or tissues

$$H_E = \sum_T w_T H_T$$

gsf 1988	The effective dose equivalent as defined in DIN 6814 T 5	

The risk coefficients (ICRP 26 § 38)

are age and sex averaged,

which means

$$a_T = \frac{1}{2}(a_T^{\male} + a_T^{\female})$$

$$p = \frac{1}{2}(p^{\male} + p^{\female})$$

$$p = \sum_T p_T = \sum_T a_T H_T$$

and $$\sum_T (a_T^{\male} + a_T^{\female}) H_T = \sum_T (a_T^{\male} H_T^{\male} + a_T^{\female} H_T^{\female})$$

The organ dose H_T

for the determination of H_E is defined as

$$H_T(\text{ICRP 26}) = \frac{a_T^{\male} H_T^{\male} + a_T^{\female} H_T^{\female}}{a_T^{\male} + a_T^{\female}}$$

gsf 1988	The organ dose H_T ICRP 26	

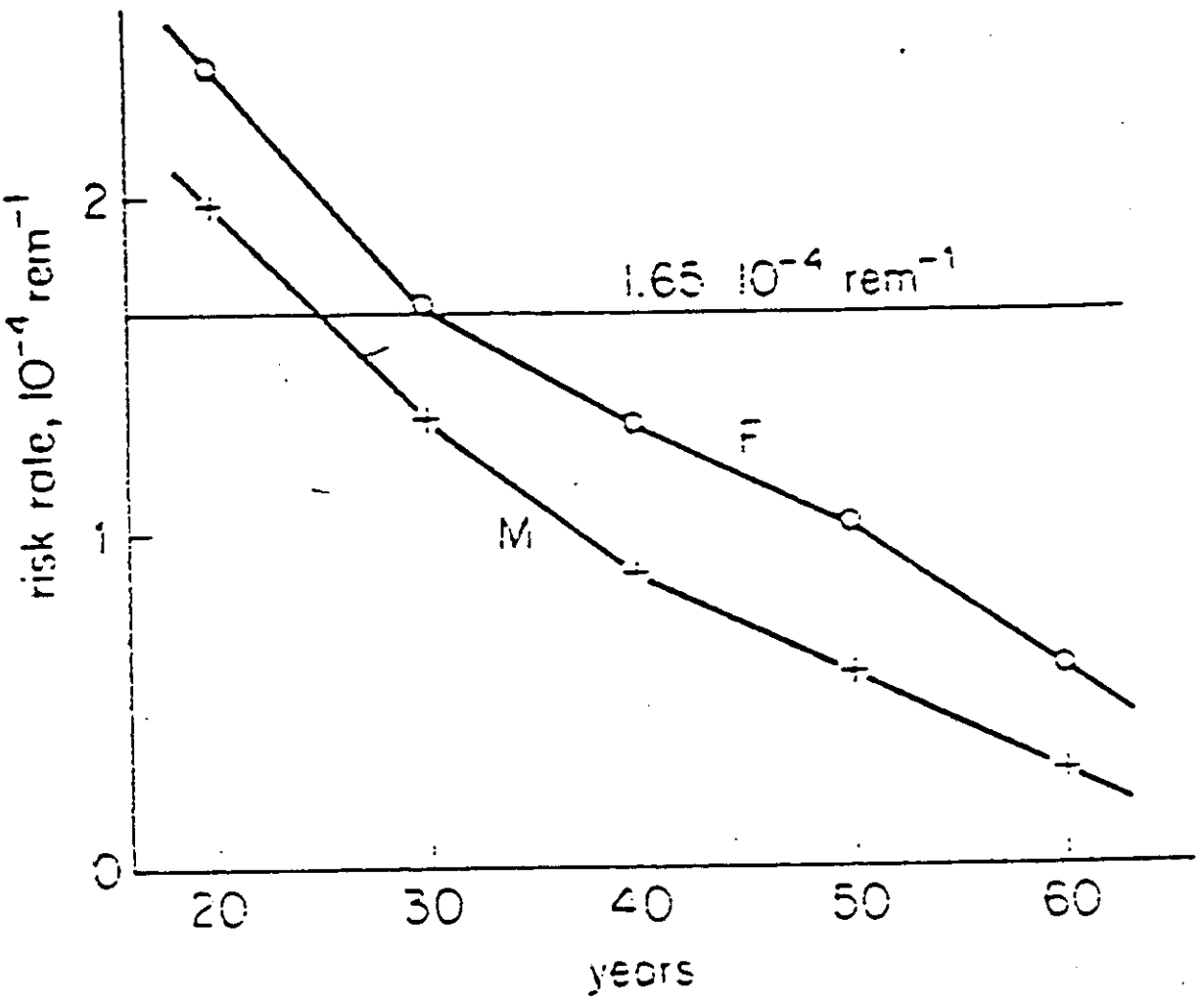

FIG. 4. Variation with age and sex of risk (somatic + genetic) relative to nominal value of 1.65 10^{-4} rem^{-1} adopted for radiation protection purposes by ICRP, this value being made up of 0.4 10^{-4} rem^{-1} genetic, and 1.25 10^{-4} rem^{-1} as the mean value between that for males (1.0 10^{-4} rem^{-1}) and females (1.5 10^{-4} rem^{-1}) for a complete expression of carcinogenic risk.

Risikogewichtete Dosisgrößen pro Photonen-äquivalentdosis	100 keV		1 MeV		10 MeV	
	♂	♀	♂	♀	♂	♀
H_E Sv/Sv	1.44		1.05		1.00	
H_{eff}^{Av}* Sv/Sv	1.51	1.39	1.04	1.05	1.00	0.99
H_{eff}^{20}* Sv/Sv	1.59	1.36	1.07	1.07	1.02	0.99
H_{eff}^{50}* Sv/Sv	1.29	1.39	0.96	1.03	0.97	1.00

Schilddrüsenuntersuchung Tc 99m (pro MBq)

Alter (Jahre)	$G_{♂}$. 10^{-6}	$G_{♀}$. 10^{-6}	$G_{♂\ Magenwand}$. 10^{-6}	$H_{eff}^{♂}$. 10^{-6} Sv	$H_{eff}^{♀}$. 10^{-6} Sv	H_E . 10^{-6} Sv
10	0.39	0.48	0.143	15.0	16.0	18.3
20	0.16	0.21	0.061	8.3	8.7	10.0
40	0.11	0.13	0.046	12.7	9.7	10.0
60	0.032	0.044	0.012	11.9	7.3	10.0

RADIATION PROTECTION

ICRP PUBLICATION 53

Radiation Dose to Patients from Radiopharmaceuticals

A report of a Task Group of Committee 2 of the International Commission on Radiological Protection

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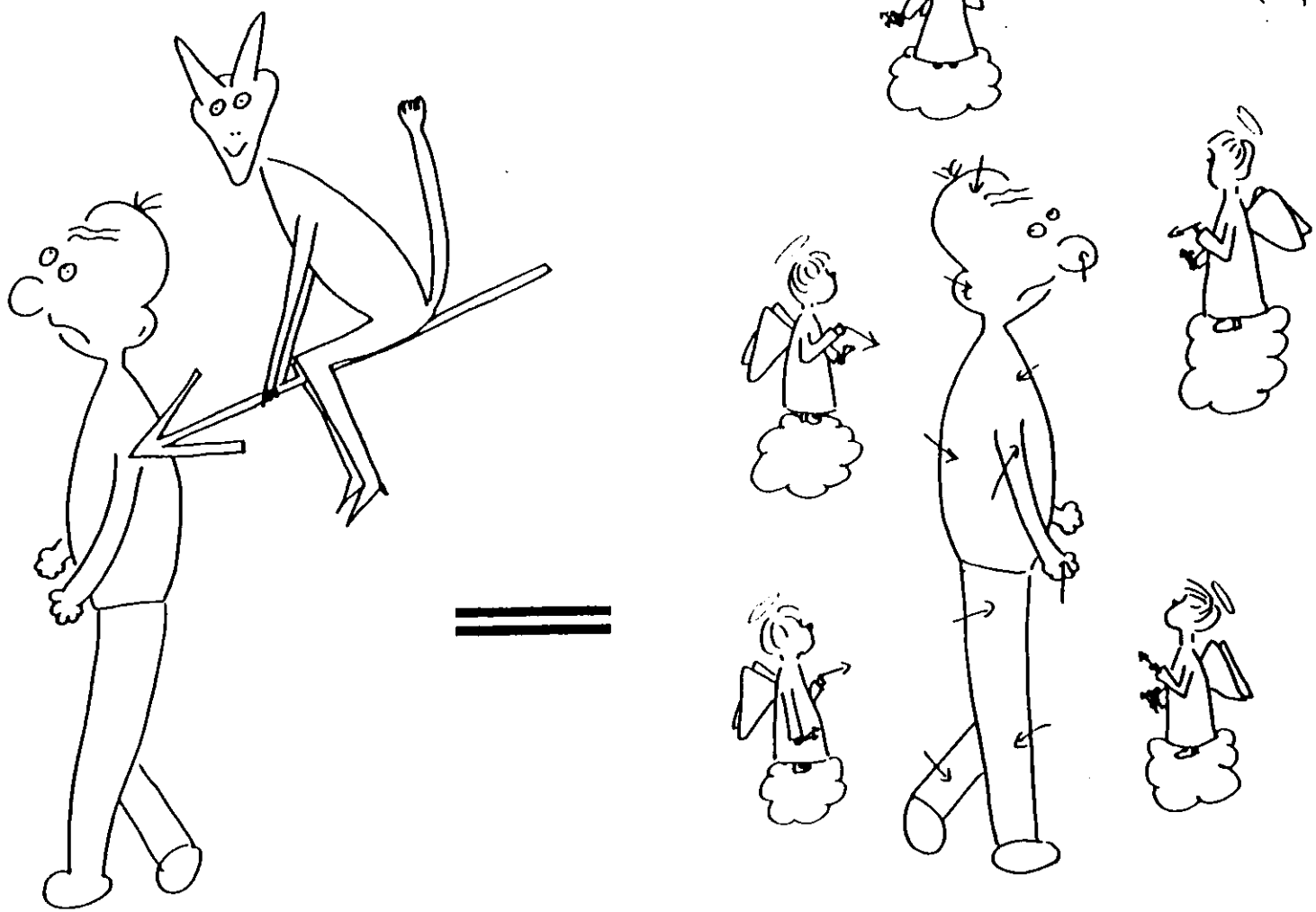
CONTENTS



gsf 1984	Prinzip der Effektivdosis	15

Reference Terms for Estimates of Radiation Dose for X-ray Mammography

X-ray mammography is being used increasingly and, in many countries, efforts have been made to undertake risk-benefit and cost-benefit studies for x-ray mammography applied to various age groups. At present there is considerable variation in the way the radiation dose is expressed and there is a need for standardisation so that an adequate assessment of radiation dose may be made, and for such estimates to be comparable from country to country.

The female breast is a composite of adipose and glandular tissues. The glandular tissue, including the acinar and ductal epithelium and associated stroma, is more vulnerable to radiation carcinogenesis than the skin, adipose tissue, or areola. Therefore, the average absorbed dose in the glandular tissue, excluding the skin layer, is the preferred quantity for assessing radiation risk from x-ray mammography. Other quantities, such as average absorbed dose in the whole breast, in the skin, or in a small volume of tissue at the midplane of the breast, have been used in the past as a convenience, in the absence of specific data on average absorbed doses in the glandular tissue. There are now extensive data available that permit calculation of average absorbed dose in the glandular tissue (20, 21), and therefore the use of the preferred quantity can be implemented readily.

Most women undergoing routine x-ray mammography without symptoms are 40 years of age or older. Therefore, the reference breast should have a tissue composition with substantial adipose content to take account of this. A composition of 50% adipose and 50% glandular tissue distributed uniformly in the breast has been adopted by investigators in the field [20,22,23,24].

The critical dimension affecting absorbed dose to the breast in x-ray mammography is thickness of the breast. In x-ray mammography, the breast is compressed to achieve better images, either by firm compression to a nearly uniform thickness, or by less compression which results in a conical geometry. A uniform breast thickness after firm compression has been adopted as a reference dimension [20,22,23,24].

The Commission therefore recommends that the usual reference terms for radiation dose estimation from x-ray mammography be the average absorbed dose in the glandular tissue (excluding skin) in a uniformly compressed breast of 50% adipose, 50% glandular tissue composition. The reference breast thickness should be specified.

The Calculation of Dose from External Photon Exposures Using Reference Human Phantoms and Monte Carlo Methods

Part III: Organ Doses in X-Ray Diagnosis

G. Drexler, W. Panzer, L. Widenmann,
G. Williams and M. Zankl

Institut für Strahlenschutz

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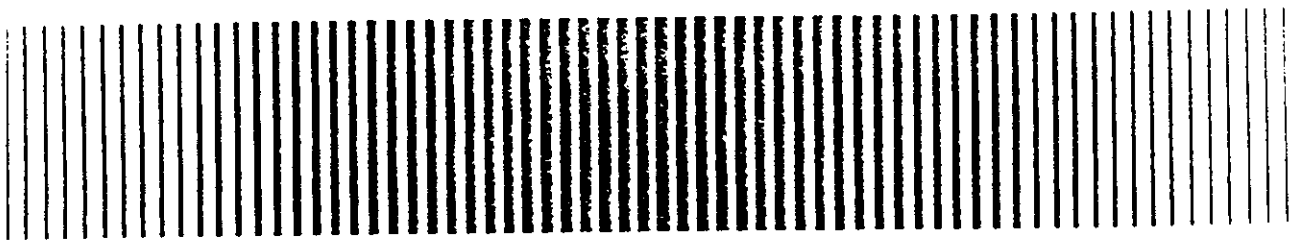

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3. Instrumentation

-- equipment specification

-- Q.A

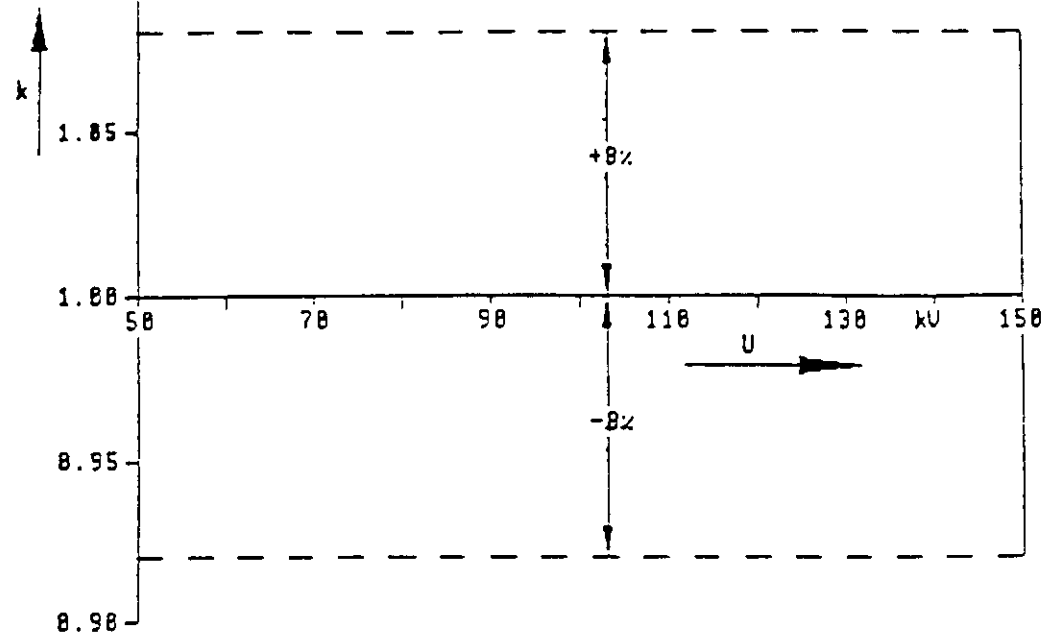
-- radiation protection

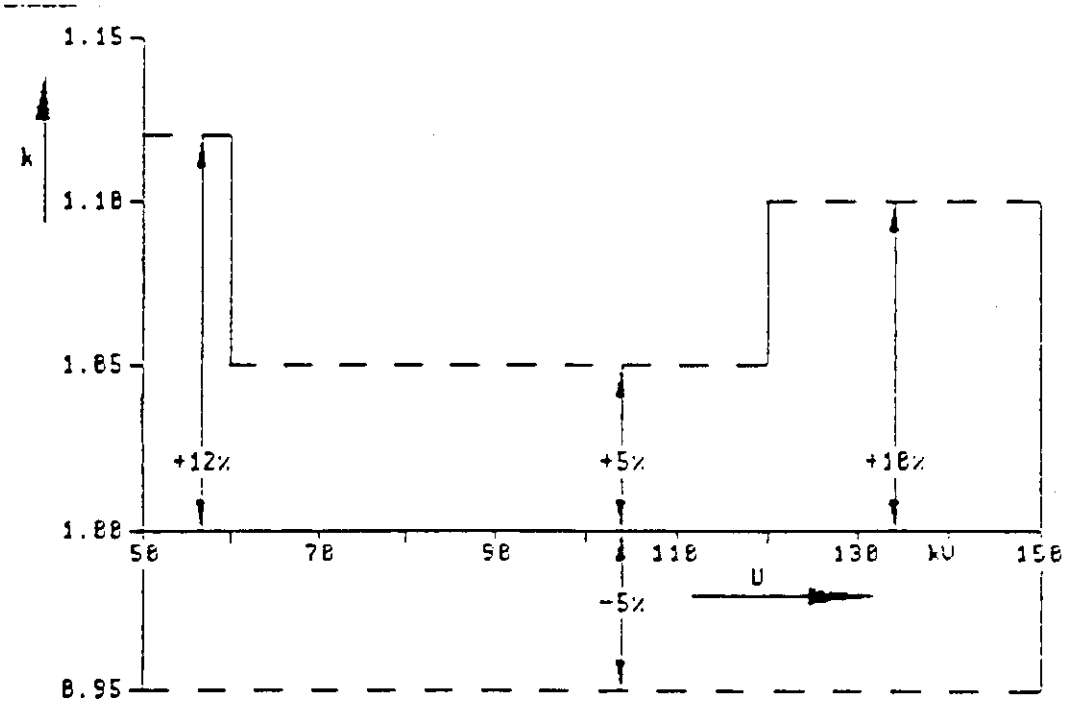
Maximum variation of response on the variation of an influence quantity within its nominal range

influence-quantity	nominal range	reference value	f in %
radiation quality	acc. to manufacturer	70 kV	see fig.
doserate (for dosimeters)	acc. to manufacturer	-----	±4
direction of rad. incidence	5°	direction of preference	±3
Supply voltage	acc. to manufacturer	nominal value	±3
pressure	800hPa to 1060hPa	1013 hPa	±3
ambient temperature	15°C bis 30°C	20°C	±3
rel. humidity	20% to 75 % max. 20 g/m	60 %	±3
elec. and magn. interference		absense of interference	±5

The Need for an Intercomparison of Diagnostic Dosimeters and its Realization

H.M. Kramer
Physikalisch-Technische Bundesanstalt, D-3300 Braunschweig





The correction factor k for the energy dependence of a diagnostic dosimeter must lie within the range between the broken lines.

U: tube voltage
(a) refers to measurements without a phantom,
(b) to measurements behind an aluminium phantom according to DIN 6872.

The Need for an Intercomparison of Diagnostic Dosimeters and its Realization

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Physikalisch-Technische Bundesanstalt, D-3300 Braunschweig

Average diagnostic x-ray examinations by level of health care

Level of health care	Annual examinations per 1000 population	Population per x-ray machine
I	800	4000
II	150	20000
III	50	80000
IV	< 30	170000

PROPOSAL OF AN OUTLINE ON A GUIDELINE FOR DOSIMETRY IN DIAGNOSTIC RADIOLOGY

(Elaborated by a group of experts
of the Commission of the European Communities)

1.) INTRODUCTION: Task of the Dosimetry in Quality Assurance in Medical Diagnostic Radiology

- 1.1. Acceptance testing
- 1.2. Repair and maintenance testing
- 1.3. Constancy testing

2.) Requirements on Dosemeter-Measurement Requirements

- 2.1. Output and output rate
- 2.2. Area-exposure-product meters
- 2.3. Dosemeters for measuring dose per optical density (about 1)

3.) Requirements on Accuracy, Limits according to Clinical Needs (Specification of radiation-quality, dose rate and dose ranges)

- 3.1. Output-dose and output-dose rate
- 3.2. Area-exposure dosemeters
- 3.3. Dosemeters for measuring dose and dose rate at the image receptor

4.) Available Dosemeters and Measuring Methods

- 4.1. Ionisation dosemeters
- 4.2. Thermoluminescent dosemeters
- 4.3. Other dosemeters

5.) Calibration Laboratories

- 5.1. Standard laboratories
- 5.2. Secondary standard laboratories
- 5.3. Other secondary calibration laboratories

6.) Necessity of Intercomparison-Methods and Programs

- 6.1. Intercomparison of radiation measurements in radiodiagnostic services
- 6.2. Intercomparison of radiation measurements in quality-assurance and -control (Acceptance maintenance and constancy)

7.) Perspective for Future Development in Dosemeters and Measuring Methods

8.) Guidelines for Appropriate Measuring Methods and Desing of Instrumentation including Dose Ranges, Ranges of Radiation, Justification, Accuracy and Evaluation of Uncertainties