Contents

Prefac	e	
Summary		
Symbo	ols and Acronyms	
1. Int	roduction	
2. Qua 2.1 2.2	antities Relevant to Beta Ray Dosi Dosimetric Requirements Operational Quantities and their Mea	
3. Ana 3.1 3.2 3.3 3.4	atomical and Radiobiological BasiIntroductionShort Anatomical DescriptionStochastic Effects of Beta Radiation: 0Deterministic Effects of Beta Radiation 3.4.1 Early (Acute) Deterministic Eff 3.4.2 Late (Chronic) Deterministic Eff	
3.5 3.6	Special Cases 3.5.1 Hot Particles 3.5.2 Low-Energy Beta RaysLimits on Skin Dose	
4. Bet 4.1 4.2 4.3	a Ray Sources and Spectra Sources of Beta-Ray Hazards Calculation of Beta-Ray Spectra Effects of Source Covering and Trans	
5. Phy 5.1 5.2	 vsics of the Interaction of Electron Inelastic Interactions: Energy Loss 5.1.1 Collision Stopping Power 5.1.2 Collision Energy-Loss Stragglin 5.1.3 Transport of Energy by Second in Ionization Events 5.1.4 Radiative Stopping Power 5.1.5 Range Elastic Scattering 5.2.1 Single Scattering 5.2.2 Multiple Scattering 	
6. Cal 6.1 6.2	culation of Dose Distributions Analytical or Deterministic Methods. Monte Carlo Methods	
6.4	 6.3.1 Isotropic Point Source in an In 6.3.2 Surface Sources 6.3.3 Normally-Incident Parallel Bea 6.3.4 Effect of Angle of Incidence Boundary Effects and Backscattering 	
6.5	Equivalent Thicknesses of Various Ma	
6.6	6.6.1 The Point-Source Function	
6.7	Integration by the VARSKIN Code	

	iii
· · · · · · · · · · · · · · · · · · ·	v
·····	xi
	1
Dosimetry	2
	2
Measurement	2
Basis of Skin Dosimetry	5
	5
····	5
lon: Cancer Induction	0 5
	0 E
	0 6
LIC Effects	D C
•••••••••••	0
••••••	0 C
••••	0
•••••••••••••••••••••••••	1
• • • • • • • • • • • • • • • • • • • •	8
	8
	8
ransmission in Air	10
tuong with Matton	19
arons with Matter	12
58	12
·····	12
condary Radiation Produced	19
	14
	15
	15
	15
	15
	16
	10
••••••••••••••••••••••••••••••••••••••	10
ous	10
d TICED Somias (ITS) Codes	10
TGEN Derles (115) Codes.	20
(EGS) (Oues	20
	21
un Infinito Medium	22
	22
1 Beams	20
A	20
	25
15 Materials: Scaling	27
ped Dose Distributions	21
	29
D	29
ource Function	30
le	31

Contents

ICRU Report 56, 1997

6.8 Dose Equivalents from Airborne Releases	31
 7. Measurement Techniques 7.1 Introduction 7.2 General Characteristics and Requirements 7.2.1 Area Survey Instruments 7.2.2 Individual Dosimeters 7.3 Extrapolation Chambers 7.3.1 Fundamentals 7.3.2 Extrapolation Chamber Construction 	33 33 33 34 35 35 36
 7.3.3 General Guidelines for Extrapolation Chamber Measurements 7.3.4 Perturbation Correction 7.3.5 Extrapolation to Bragg-Gray (BG) Conditions 7.3.6 Measurement Uncertainty 7.4 Ionization-Chamber Survey Meters 7.5 Proportional Counters 7.6 Geiger-Müller (GM) Counters 7.7 Scintillation Detectors 7.8 Semiconductor Counters 7.9 Beta-Ray Spectrometers 7.10 Thermoluminescent Dosimeters (TLD's) 7.10.1 Physically-Thin Detectors 7.10.2 Surface-Sensitive Detectors 7.10.2 Multi Element Desimeters 	36 38 39 39 42 42 43 43 44 45 46 47
7.10.4 Special Heating Regimes and/or Glow-Curve Analysis	51
 7.11 Thermally-Stimulated Excelectron Emission (TSEE) Detectors 7.12 Photographic Films	51 52 53 54 56
 8.1.1 Instrument Performance	56 56 57 57 57 57 59 60
 9. Beta-Ray Measurements in Special Circumstances 9.1 Introduction 9.2 Measuring Skin Dose at Very Shallow Depths 9.3 Skin Dosimetry for Large Accidental Doses 9.3.1 Physical Dosimetry 9.3.2 Biological Dosimetry 9.4 Hot-Particle Dosimetry 9.4.1 Dosimetry Requirements 9.4.2 Some Possible Dosimetry Techniques 9.5 Doses from Radioactive Materials Penetrating into the Skin 9.6 Doses in Mixed Fields of Alpha and Beta Radiation 	63 63 63 64 64 64 65 65 66
10. Standard Sources and Calibrations 10.1 Introduction 10.2 Secondary-Standard Sources 10.3 Calibrations and Type Testing 10.3.1 Dose-Rate Meters and Dosimeters	68 68 68 69 69

10.3.2 Calibration Phantoms. 10.3.3 Beta-Ray Sources	71 71
Appendix A. Composition and Characteristics of Materials	72
Appendix B. Tables of Stopping Powers and Ranges of	
Electrons	75
Appendix C. Absorbed Dose Distributions; Conversion	
Factors	92
U.I Monoenergetic Electrons.	92
C.1.1 Isotropic Point Source in an Infinite Medium	92
C 1.3 Variation of Absorbed Description Angle of Ingidence	94 02
C.2. Bata Radiation	92 Q2
C.2.1 Isotronic Point Source in an Infinite Medium	92
C.2.2 Surface Sources: Skin Contamination	92
C.2.3 Normally-Incident Parallel Beams	93
C.3 Conversion Factors for Fission Products in the Air or on the	
Ground	93
Tables	
C.1 Scaled absorbed dose distributions in an infinite water	
medium, from point isotropic sources of monoenergetic	
electrons	93
C.2 Scaled absorbed dose distributions for broad beams of	
monoenergetic electrons incident normally on water	94
C.3 Values of absorbed dose/fluence at 0.07 mm depth in water,	
irradiated by broad beams of monoenergetic electrons	
incident at various angles.	94
U.4 Values of absorbed dose/fluence at 0.4 mm depth in water,	
incident et verieue englee	04
C 5 Values of absorbed dose/fluence at 3 mm denth in water	34
irradiated by broad beams of monoenergetic electrons	
incident at various angles.	95
C.6 Values of absorbed dose/fluence at 10 mm depth in water,	
irradiated by broad beams of monoenergetic electrons	
incident at various angles	95
C.7 Values of absorbed dose/fluence at 0.07 mm depth in tissue,	
irradiated by broad beams of monoenergetic electrons	
incident at various angles	95
C.8 Values of absorbed dose/fluence at 3 mm depth in tissue,	
irradiated by broad beams of monoenergetic electrons	05
Incluent at various angles	90
irradiated by broad beams of monoenergetic electrons	
incident at various angles	95
C.10 Distributions of absorbed dose rate in an infinite water	
medium, from point and plane sources of beta rays from	
various nuclides	96
C.11 Distributions of absorbed dose rates in water, averaged over	
1 cm^2 , from point beta-ray sources on the surface	98
U.12 Distributions of absorbed dose rates in water, averaged over	100
100 cm ⁴ , irom point beta-ray sources on the surface	100
1 cm ² from point bata-ray sources on the surface	109
C.14 Absorbed dose rates at four denths in water averaged over	104
100 cm^2 . from point beta-ray sources on the surface	103
C.15 Distributions of absorbed dose rates in water irradiated by	

Contents

ICRU Report 56, 1997

normally-incident, broad beams of beta rays from various
nuclides 104
C.16 Absorbed dose rates at 4 depths in water irradiated by
broad, normally-incident beams of beta rays from various emitters
C.17 Dose equivalents at 0.07 mm depth in water, from various
beta emitters distributed in infinite clouds or over the
ground 106
Appendix D. Calculated Beta-Ray Spectra
Appendix E. Glossary 110
References
CRU Reports

SYMBOLS and ACRONYMS

Α	relative atomic mass
8	shape factor for a beta spectrum
$\frac{\alpha_n}{B}$	backscatter factor
BG	Bragg-Gray conditions
CSDA	continuous slowing down approximation
с С	velocity of light
C	narameter in Loevinger's equations
D(d)	personal absorbed dose at depth d mm
$D_{p}(d)$ $D'(d,\vec{\Omega})$	directional absorbed dose at depth <i>d</i> mm on a ra
D(a, st) $D_{-1}(z, a)$	absorbed dose at distance z from a plane source
$\dot{D}_{Pl}(z, u)$	absorbed dose rate in ICRU tissue (may denote)
$D_{\rm t}$ $D(\mathbf{r} \mathbf{F})$	absorbed dose at distance r per point-source ale
D(T, L) D(T) $D'(T)$	absorbed dogo rate at distance r, per point-source end
$\dot{D}(r), D(r)$	absorbed dogo rate at distance /
D(z)	donth in a madium
	depth in a medium
$a_{\rm s}$	tissue thickness equivalent to air thickness s
E	kinetic energy of an electron
$E_{\rm max}$	maximum kinetic energy of a beta spectrum
$\frac{E_{\rm res}}{\overline{D}}$	residual maximum energy of beta particles
E	mean kinetic energy of a beta spectrum
e	charge on the electron
e	base of natural logarithms
$H_{\rm p}(d)$	personal dose equivalent at depth a mm
$H'(\mathbf{d},\Omega)$	directional dose equivalent at depth a mm, on a
H_{T}	dose equivalent averaged over an organ
$H_{\rm GO}$	dose equivalent averaged over the testes
1	mean excitation energy, ionization current in an
150	International Organization for Standardization
$\mathbf{j}(\mathbf{r}/\mathbf{r}_{0}, \mathbf{E})$	scaled absorbed dose at distance r , for electrons
ł M	spacing of extrapolation champer electrodes (cha
	molar mass
M_{β}, M_{γ}	dosimeter reading from p or γ rays
m_{e}	rest mass of electron (or positron)
m _e c-	air mass in the consitive volume of an extrapolat
$n_{\rm air}$	air mass in the sensitive volume of an extrapolat
	number of alographic Mov $^{-1}$ disintegration $^{-1}$ at a
N(W)	Augradue's constant
IV _A	Avogadro s constant
p P	distance from a point source
n D	ulstance from a point source (0.07)
R_{β}	p-ray response of a detector relative to $H_p(0.07)$
$\frac{n_{\gamma}}{R}$	γ -ray response of a detector relative to $\Pi_p(0.07)$
r	distance from a point source
r-	CSDA range of an electron
r o	maximum range of bota rays
max S	total linear stopping power
S S/a	total mass stopping power
S/p	lineer colligion stopping power
	linear radiative stopping power
S _{rad}	linear radiative stopping power
~w SF	screening factor in hets docey
6 01	distance along an electron track
s ^{BG}	austient of stanning nowers of ICRU tissue and
$T^{\mathrm{s}_{\mathrm{t,air}}}$	kinetic energy of an electron
\dot{T}	maximum kingtie angress of a hota ray angetrum
- max	maximum kinetic energy of a beta-ray spectrum

X

a radius having direction $\vec{\Omega}$ ce of radius ate $\dot{D}'(d)$ or $\dot{D}_{\rm p}(d)$) electron of energy E

a radius having direction $ec{\Omega}$

an extrapolation chamber n ns of energy *E* chamber depth)

lation chamber

t energy W in a beta-ray spectrum

nd air under Bragg-Gray conditions

ım