

Contents

Preface	iii
1. Introduction	1
1.1 Rationale for Proton Therapy	1
1.2 History of Proton Therapy	2
1.3 Scope of this Report	4
1.4 Relation to Existing Reports	5
2. Production of Proton Beams for Therapeutic Applications	6
2.1 Accelerators	6
2.1.1 Cyclotrons	6
2.1.1.1 Synchrocyclotrons	6
2.1.1.2 Isochronous Cyclotrons	7
2.1.2 Synchrotrons	7
2.1.3 Linear Accelerators	8
2.2 Typical Operating Parameters	8
2.3 Beam Shaping and Delivery	8
2.3.1 Passive Scattering Techniques	8
2.3.2 Wobbling and Beam Scanning	9
2.3.3 Spot Scanning	10
3. Pertinent Quantities and Units	11
3.1 Physical Quantities	11
3.2 Radiometric Quantities	11
3.3 Interaction Coefficients	11
3.4 Dosimetric Quantities	12
3.5 Stochastic Quantities	12
4. Proton Interactions with Matter	13
4.1 Electromagnetic and Nuclear Interactions	13
4.2 Energy Deposition	13
4.2.1 Average Energy Loss	13
4.2.2 Microdosimetric Concepts	14
4.3 Factors which Affect Proton Beam Characteristics	14
5. Determination of Proton Absorbed Dose in Reference Conditions	15
5.1 General Considerations for Proton Dosimetry	15
5.2 Fluence Measurements with a Faraday Cup	16
5.3 Absorbed Dose Measurements with a Calorimeter	17
5.4 Absorbed Dose Measurements with an Ionization Chamber	18
5.4.1 Introduction	18
5.4.2 Conceptual Description of Absorbed Dose Determination	18
5.4.3 Interpretation of Ionization Chamber Response	19
5.4.3.1 Considerations of Stopping Power	19
5.4.3.2 Considerations of w and W	21
5.4.4 Determination of Absorbed Dose to Water	26
5.4.4.1 Determinations Based on Fluence	26
5.4.4.2 Determinations Based on Air Kerma Calibrations	27
5.4.4.3 Determinations Based on Absolute Dose to Water Calibrations	27
6. Beam Monitoring and Relative Dosimetry	29
6.1 Beam Monitoring	29
6.1.1 Detectors for Monitoring Beam Intensity	29
6.1.1.1 Ionization Chambers for Beam Monitoring	29

6.1.1.2 Other Beam Monitoring Detectors	32
6.1.2 Special Considerations for Monitoring of Dynamic Beam Delivery	32
6.2 Dose Distributions	33
6.2.1 Detectors for Dose Distribution Measurements	33
6.2.1.1 Silicon Diodes	33
6.2.1.2 Films	34
6.2.1.3 Other Detectors for Relative Dosimetry	34
6.2.2 Determination of Dose Distributions.....	35
6.2.2.1 Measurement of Beam Range and Depth Dose Characteristics	35
6.2.2.2 Lateral Dose Uniformity and Beam Penumbra	36
7. Recommendations for Determination of Absorbed Dose in a Phantom	37
7.1 General Recommendations	37
7.1.1 Reference Dosimeter	37
7.1.2 Phantom Material and Reference Depth	37
7.2 Determination of Proton Absorbed Dose to Water using a Calibrated Ionization Chamber	37
7.2.1 N_K -based Calibrated Ionization Chamber	37
7.2.2 N_W -based Calibrated Ionization Chamber	39
7.3 Determination of Proton Absorbed Dose to Water using a Calorimeter.....	39
7.4 Determination of Proton Absorbed Dose to Water using a Faraday Cup.....	40
7.5 Numerical Values of Required Quantities	40
7.6 Summary of Recommendations	41
Appendix A Quality Assurance Example	43
Appendix B Dosimetry Worksheet	44
References	46
ICRU Reports	54
Index	58

