IAEA-TRS 398 Foton Enerjilerinde Su Fantomu/Katı Fantom Ölçümleri ve Doz Kalibrasyonu

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26 Ekim 2024- İstanbul

Soğurulan Doz

- Kütle birimi başına soğurulan enerji
- SI birimi Gray (Gy)

  - ☆ 1 Gy = 1 Joule / 1 kilogram
  - ☆ 1 rad = 100 erg / 1 gram
  - ☆ 1 Gy = 100 cGy = 100 rad

- Medikal alanda deneysel çalışmalarda insan vücudunun büyük bir kısmı su olduğundan soğurucu ortam olarak su kullanılır.

Soğurulan Doz

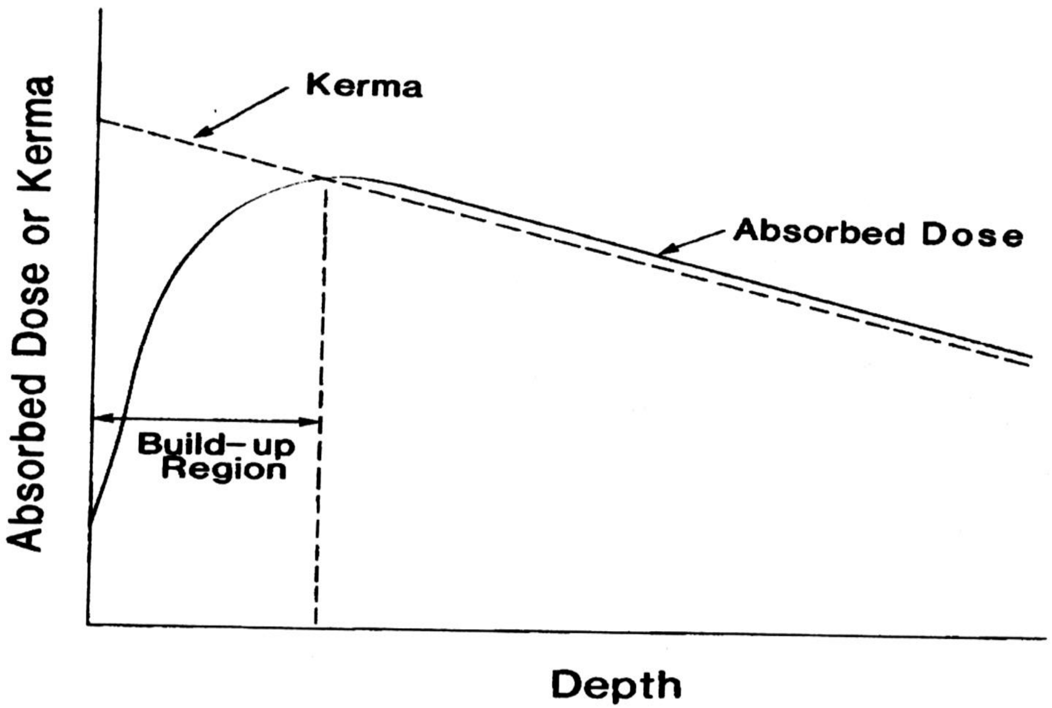
❖ Kerma (**K**inetic **E**nergy **R**eleased in **Ma**terial, sometimes per unit mass)

☞ $$K = \frac{d_{E_{tr}}}{d_m}$$ Birimi J. Kg $^{-1}$ (Gy)'dir

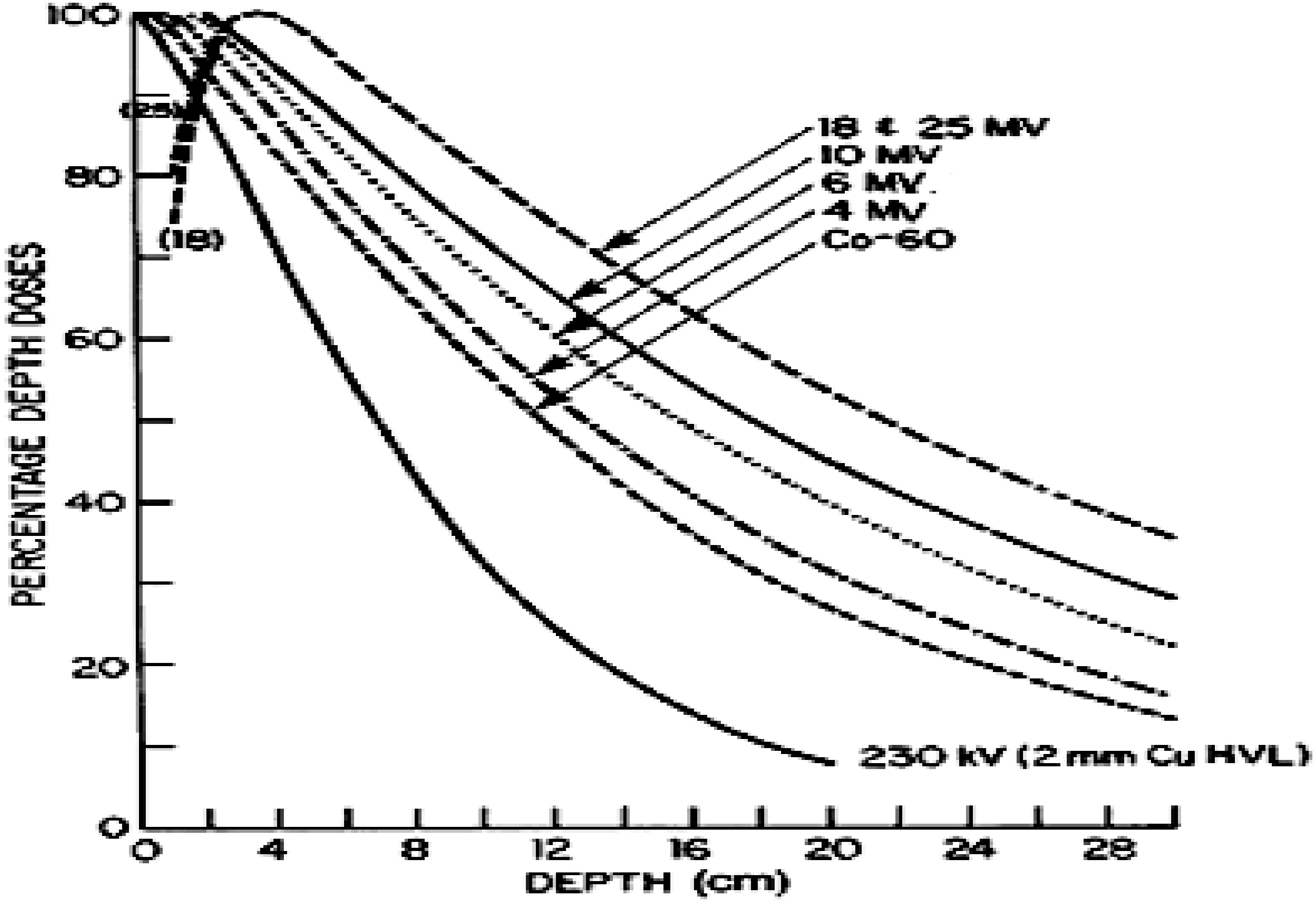
↳ $d_{E_{tr}}$: d_m kütlesinde fotonların etkileşimi ile serbest bırakılan bütün yüklü parçacıkların kinetik enerjilerinin toplamıdır.

KERMA

- Kerma (**K**inetic **E**nergy **R**eleased in **Ma**terial, sometimes per unit mass)



Derin doz eğrileri



Dozimetri Protokolleri

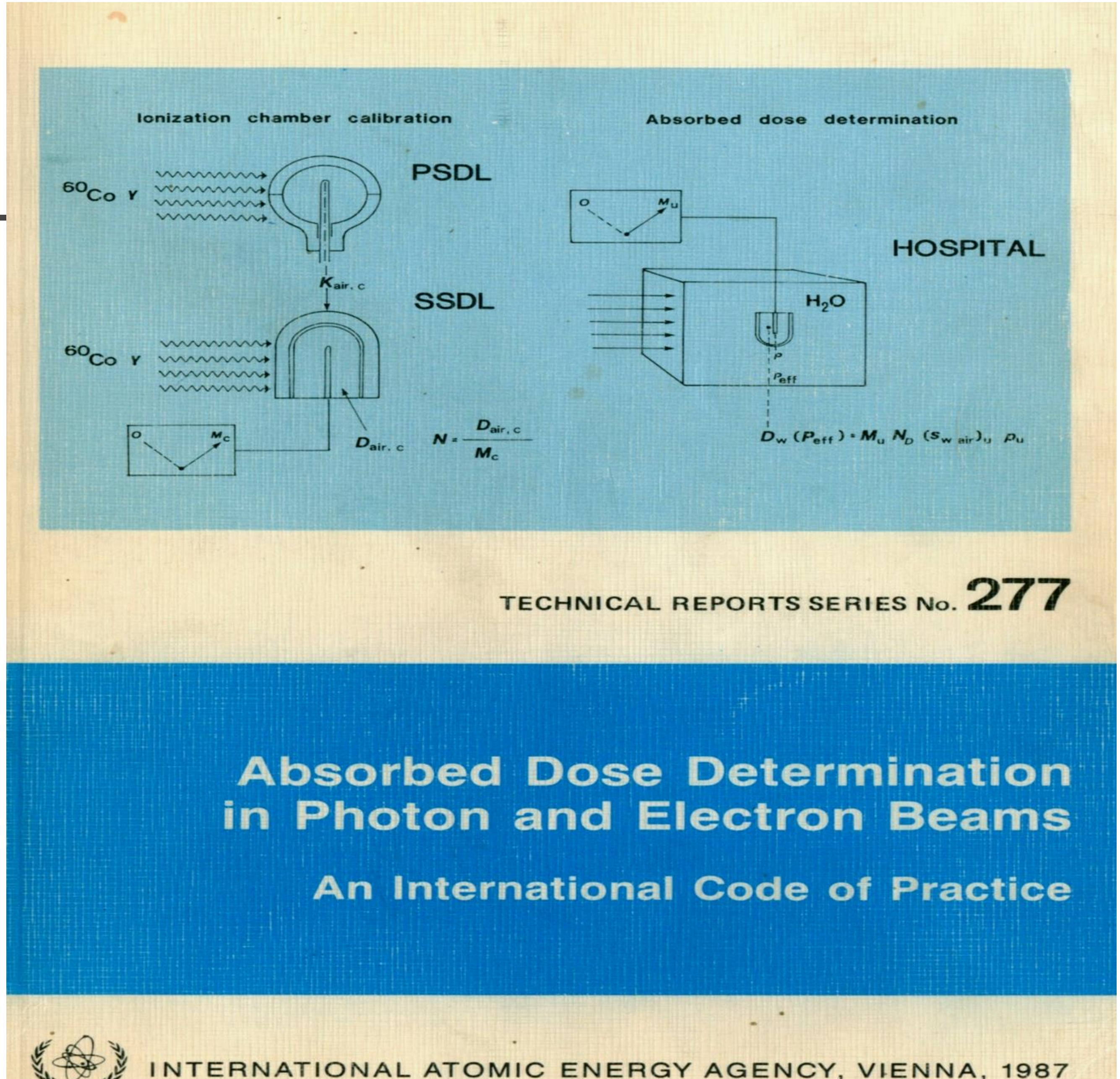
- **AAPM** (American Association of Physics in Medicine, Kuzey Amerika)
- **IPEMB** (Institution of Physics and Engineering in Medicine and Biology, İngiltere)
- **DIN** (Deutscheo Institut für Normung, Almanya)
- **NCS** (Nederlandse Commissie Voor Stralingsdosimetrie, Hollanda ve Belçika)
- **NACP** (The Nordic Association of Clinical Physics, İskandinav Ülkeleri)
- **ICRU** (International Commission on Radiation Units and Measurements, Uluslararası)
- **IAEA** (International Atomic Energy Agency, Uluslararası)

IAEA Dozimetri Protokolleri

TRS, Technical Reports Series.

- ❶ **TRS-277**, Absorbed Dose Determination in Photon and Electron Beams an İnternational Code of Practice (1987,1997).
- ❷ **TRS-374**, Calibration of Dosimeters Used in Radiotherapy (1997).
- ❸ **TRS-381**, The Use of Plane Parallel İonization Chambers in High Energy Electron and Photon Beams (1997).
- ❹ **TRS-398**, Absorbed Dose Determination in External Beam Radiotherapy (2000, 2024).

Hava Kerma Temelli Uluslararası Protokol



Ölçüm Zinciri

- Ölçüm zincirinde ilk adım kalibrasyon faktörleridir.
  - Işınlama
  - Hava Kerma
  - Soğurulan Doz
  - PSDL (Primary Standart Dosimetry Laboratory)
  - SSDL (Secondary Standart Dosimetry Laboratory)

İkincil Standart (Sekonder) Dozimetri Laboratuvarları

Türkiye'deki İkincil Standart (Sekonder) Dozimetri Laboratuvarları;

- Çekmece Nükleer Araştırma ve Eğitim Merkezi, ÇNAEM (İstanbul)
- Sarayköy Nükleer Araştırma ve Eğitim Merkezi SANAEM (Ankara)

Soğurulan Doz Ölçüm Sistemi

- Elektrometre ve İyon Odaları
- Fantomlar (su, katı su, polystyrene, acrylics)
- Referans ortam, su

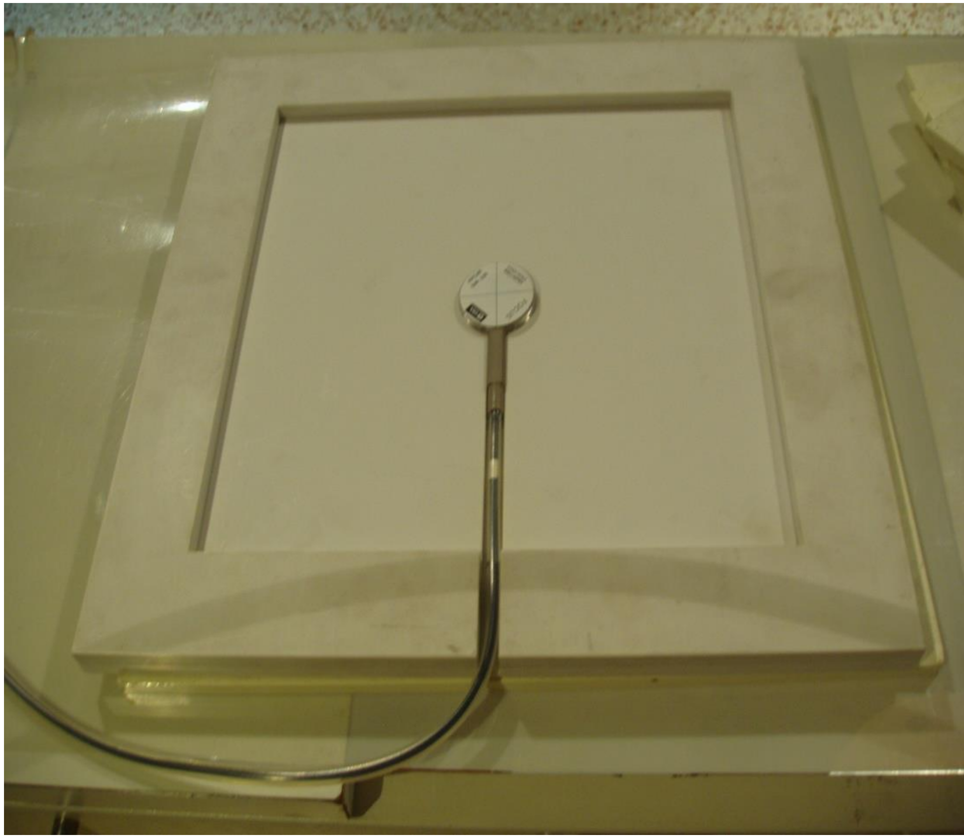
Soğurulan Doz Ölçüm Sistemi

Farmer Marka 2570/1B
Model Elektrometre

Wellhöfer Marka Dose 1
Model Elektrometre

Soğurulan Doz Ölçüm Sistemi

Silindirik iyon odası
Farmer Tipi 0.6 cc NE



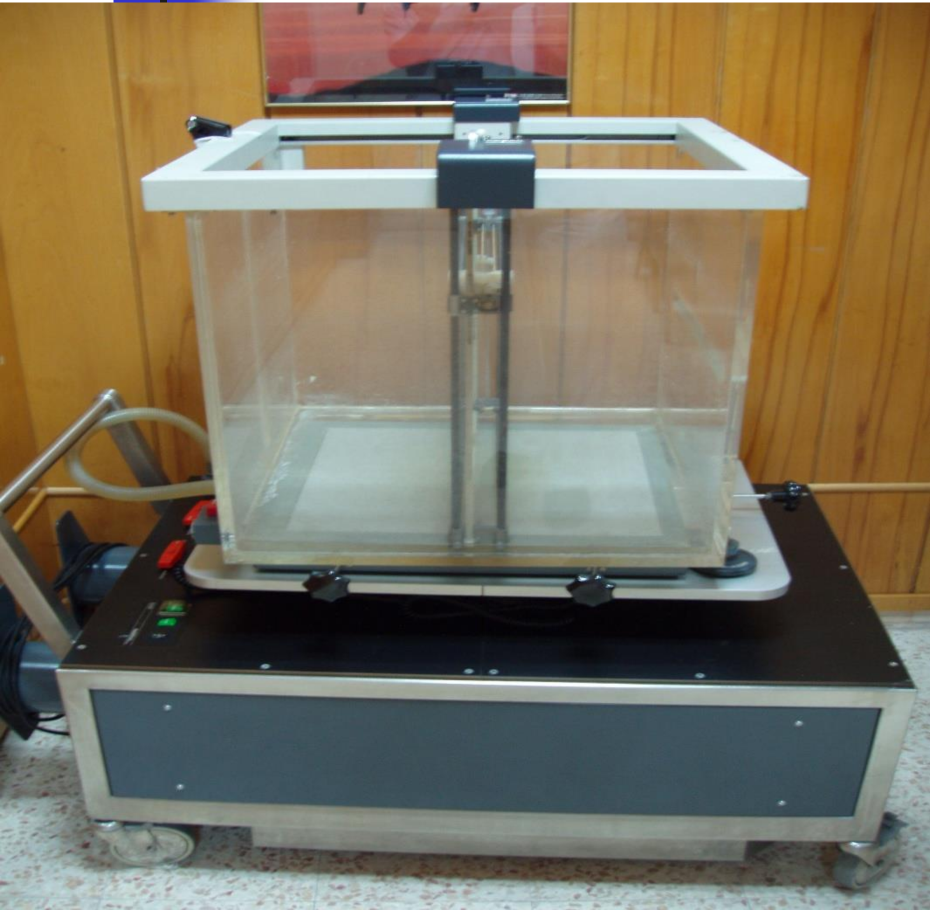
Paralel Düzlem İyon odası
Wellhöfer PPC 40

Soğurulan Doz Ölçüm Sistemi

Silindirik iyon odası (Buildup cap’li)
Farmer Tipi 0.6 cc NE

Silindirik iyon odası (Buildup cap’siz)
Farmer Tipi 0.6 cc NE

Soğurulan Doz Ölçüm Sistemi



Su Fantomu

Katı su Fantomu

İyon Odalarının Tasarımları

- Silindirik geometri tasarımlı iyon odaları ile yapılan ölçümlerde yöne bağımlılık yoktur.

- Paralel düzlem tasarımlı iyon odaları ile gelen ışınlar bir pencereden geçtikten sonra hassas hacme ulaşırlar, bu nedenle pencere ölçülecek radyasyon tarafına yönlendirilmelidir.

İyon Odaları

Silindirik iyon odaları :

- İç çapları 7 mm'den küçük, iç uzunlukları 25 mm'den kısadır.
- İyon odasının yapısı olabildiğince homojen olmalıdır.
- İyon odasının duvar materyali ve buildup cap materyalinin aynı olması gerekmez. Ancak her ikisinin bileşimi de bilinmelidir.
- Dış basınç koşulları ile çabuk dengeye gelecek şekilde dizayn edilmiştir.
- İyon odalarının karakteristikleri Tablo-II'de verilmiştir.

İyon Odaları

Paralel Düzlem iyon odaları :

- Paralel düzlem iyon odalarında plakalar arasındaki mesafe 2 mm’den ve toplayıcı elektrotların yarıçapı 20 mm’den az olmamalıdır.

- Pencerenin önü ince olmalıdır, 1 mm’den küçük olması tercih edilir.

- Kaviteyi çevreleyen materyal su eşdeğeri olmalıdır. Yani kütle çarpışma durdurma gücü ve lineer saçılma gücü su gibi olmalıdır.

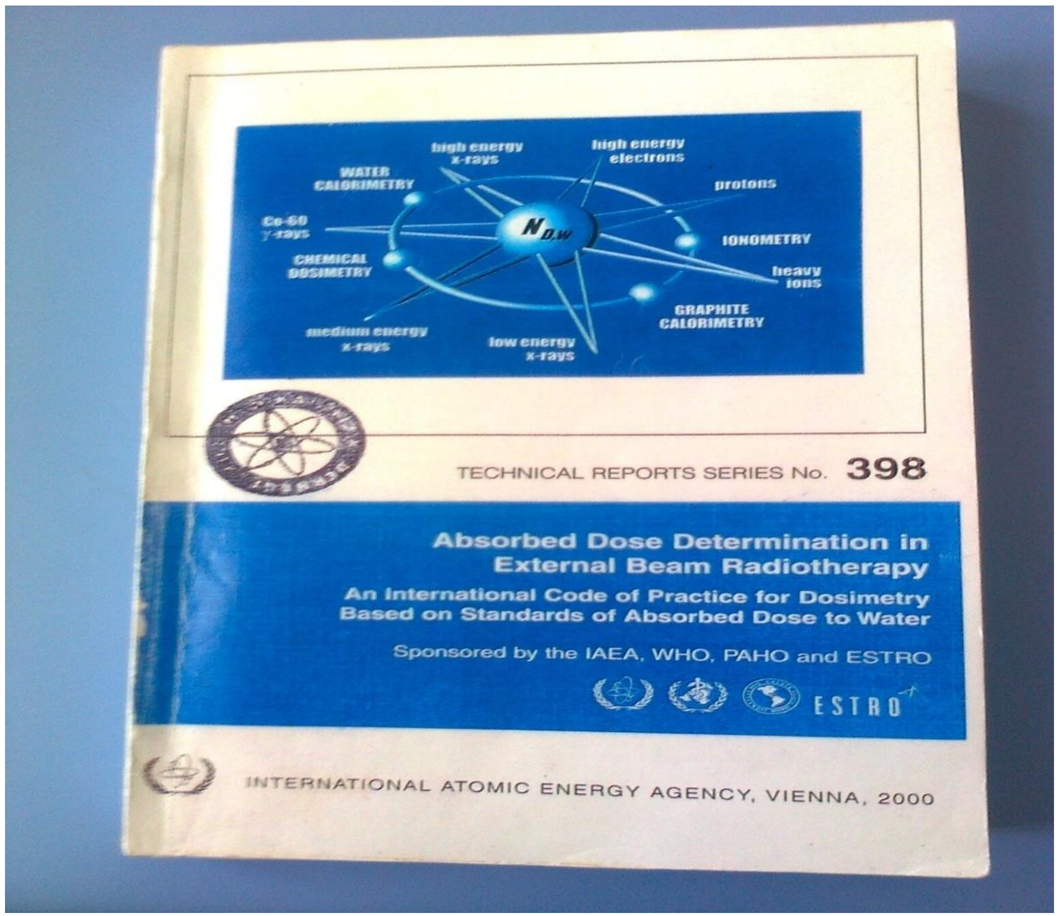
Fantomlar

- Soğurulan doz ölçümlerinde, foton ve elektron demetlerinin her ikisi için de fantom olarak su önerilir.

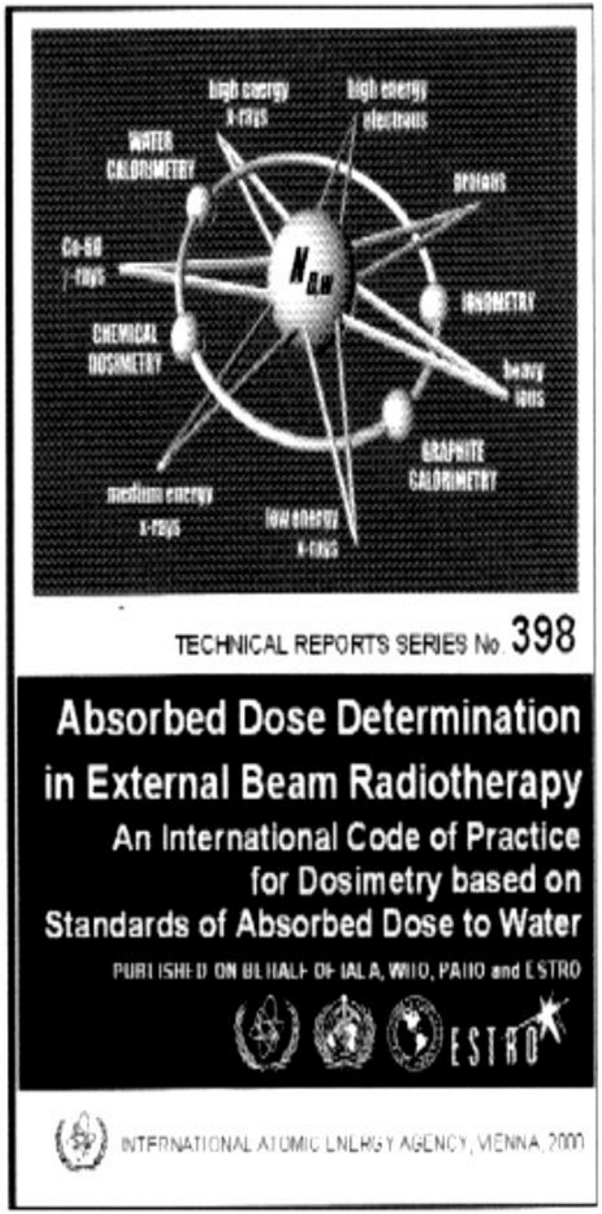
- İletken olmayan plastik fantomların kullanımı büyük dikkat gerektirir. Bu fantomlarda, birçok araştırmacı tarafından özellikle elektron demetlerinin ölçümlerinde yük birikmesi oluştuğu gösterilmiştir. Bu yük birikmesi iyon odası civarında elektrik alanı oluşturur, bu da elektron akımını kaviteye doğru yönelterek bir sinyal artışına neden olur. Bu nedenle soğurulan doz ölçümünde elektronlar için daima su ya da iletken plastik fantomlar kullanılmalıdır.

Fantom Boyutları

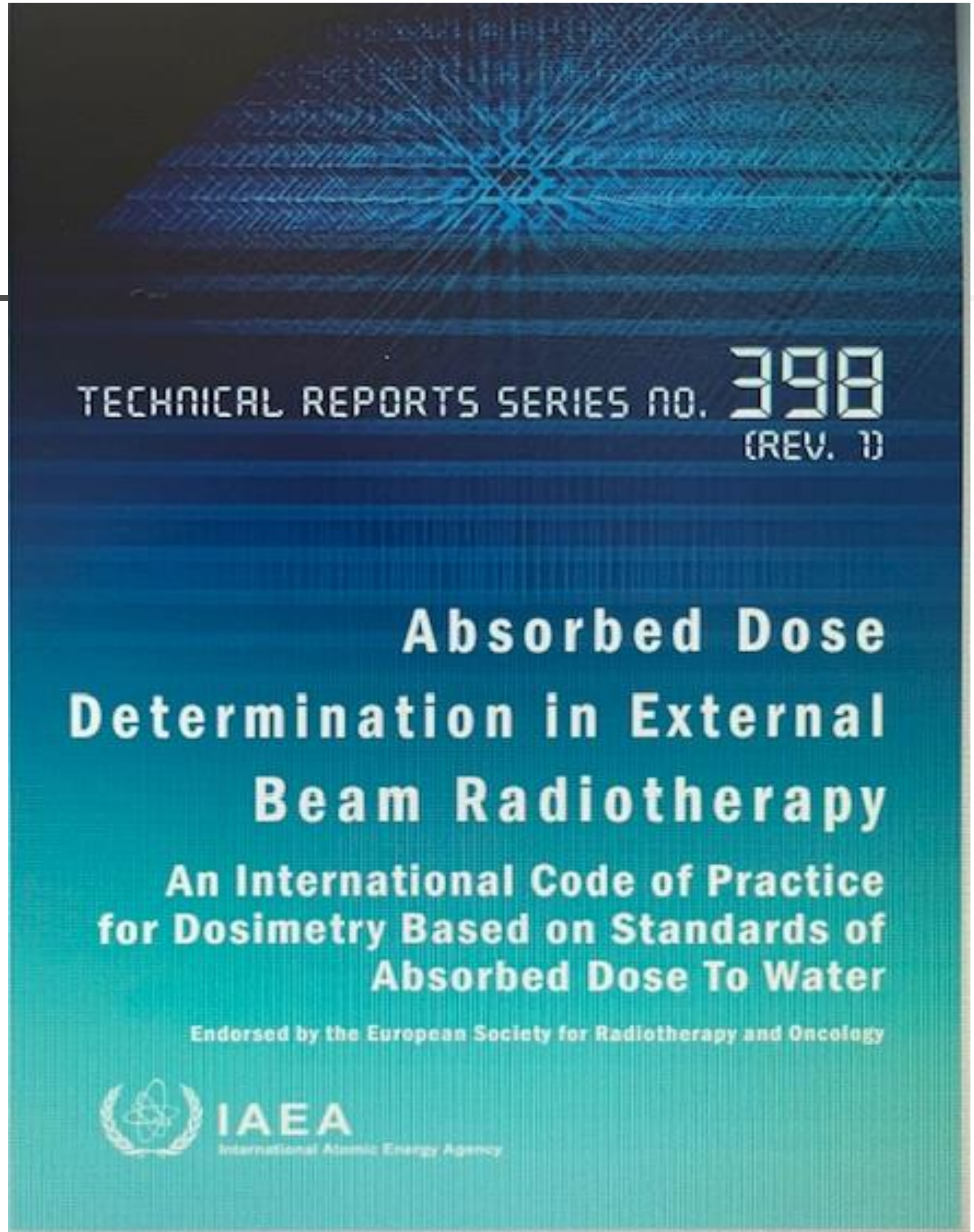
- Ölçüm derinliğinde dört kenardan en geniş alan için 5'er cm pay olmalıdır. 5 cm pay, ölçüm yapılan maksimum derinliğin ötesinde de olmalıdır.



high energy x-rays
high energy electrons
WATER CALORIMETRY
protons
Co-60 γ-rays
IONOMETRY
CHEMICAL DOSIMETRY
heavy ions
GRAPHITE CALORIMETRY
medium energy x-rays
low energy x-rays
TECHNICAL REPORTS SERIES No. 398
Absorbed Dose Determination in External Beam Radiotherapy
An International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water
Sponsored by the IAEA, WHO, PAHO and ESTRO
ESTRO
INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2000



TRS-398: published in 2000 on behalf IAEA, WHO, PAHO and ESTRO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IAEA
International Atomic Energy Agency

TECHNICAL REPORTS SERIES No. 398 (Rev. 1)

ABSORBED DOSE DETERMINATION IN EXTERNAL BEAM RADIOTHERAPY

AN INTERNATIONAL CODE OF PRACTICE FOR DOSIMETRY BASED ON STANDARDS OF ABSORBED DOSE TO WATER

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2024

TRS-398

- $N_{D,W}$ formalizm temeline dayanır.
- Q_o kalibrasyon kalitesinde

$$D_{W,Q_o} = M_{Q_o} N_{D,W,Q_o}$$

- Diğer Q kullanıcı kalitesinde (fotonlar,elektronlar, ağır parçacıklar)

$$D_{W,Q} = M_Q N_{D,W,Q_o} k_{Q,Q_o}$$

k_{Q,Q_o} : Demet kalite faktörüdür.

TRS-398 Demet Kalite Spesifikasyonu

- Foton demetleri :
  - Sabit SCD'de iki farklı derinlikteki dozların oranı $TPR_{20,10}$ (elektron kontaminasyonundan bağımsız) (^{60}Co TPR değil)

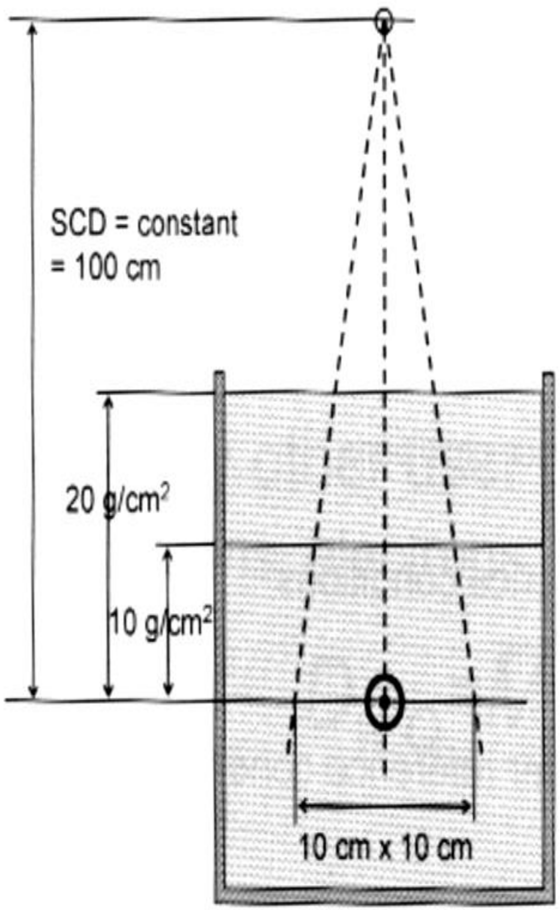
Demet Kalite Spesifikasyonu

- <u>Demet Kalitesi</u> ($TPR_{20,10}$'nun belirlenmesi):

☞ $$TPR_{20,10} = \frac{D_{20}}{D_{10}} \approx \frac{M_{20}}{M_{10}}$$

- SCD = sabit = 100 cm
- d_2= 20 g / cm^2
- d_1 = 10 g / cm^2
- Alan = 10 cm x 10 cm (SCD = 100 cm'de)

Beam Quality: determination of $TPR_{20,10}$



$\Rightarrow M_{10}$

$\Rightarrow M_{20}$

$$TPR_{20,10} = \frac{D_{20}}{D_{10}} \approx \frac{M_{20}}{M_{10}}$$

Demet Kalite Spesifikasyonu

- Demet Kalitesi :

☞ $$PDD_{20,10} = \frac{D_{20}}{D_{10}} \approx \frac{M_{20}}{M_{10}}$$

☞ $TPR_{20,10} = 1.2661\ PDD_{20,10} - 0.0595$

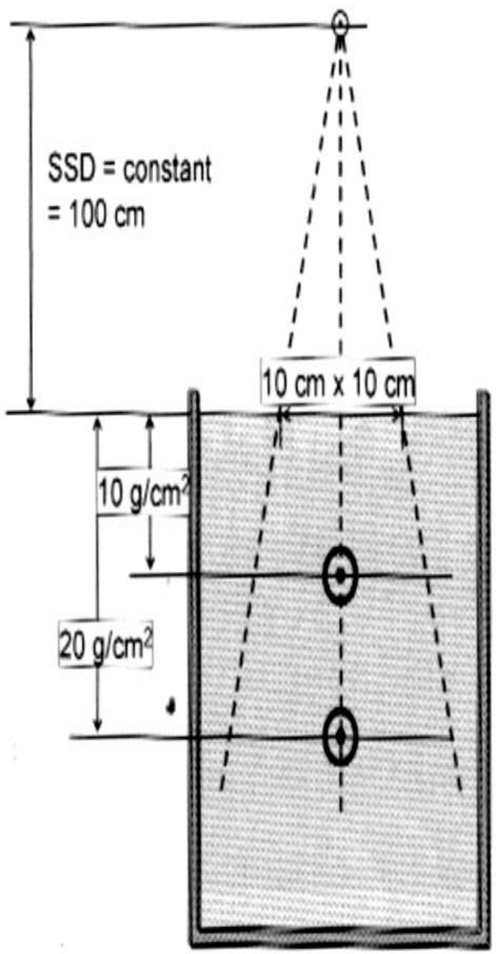
↳ SCD = sabit = 100 cm

↳ d_2= 20 g / cm^2

↳ d_1 = 10 g / cm^2

↳ Alan = 10 cm x 10 cm (SCD = 100 cm'de)

Beam Quality: determination of $TPR_{20,10}$



$\Rightarrow M_{10}$

$\Rightarrow M_{20}$

$$PDD_{20,10} = \frac{D_{20}}{D_{10}} \approx \frac{M_{20}}{M_{10}}$$

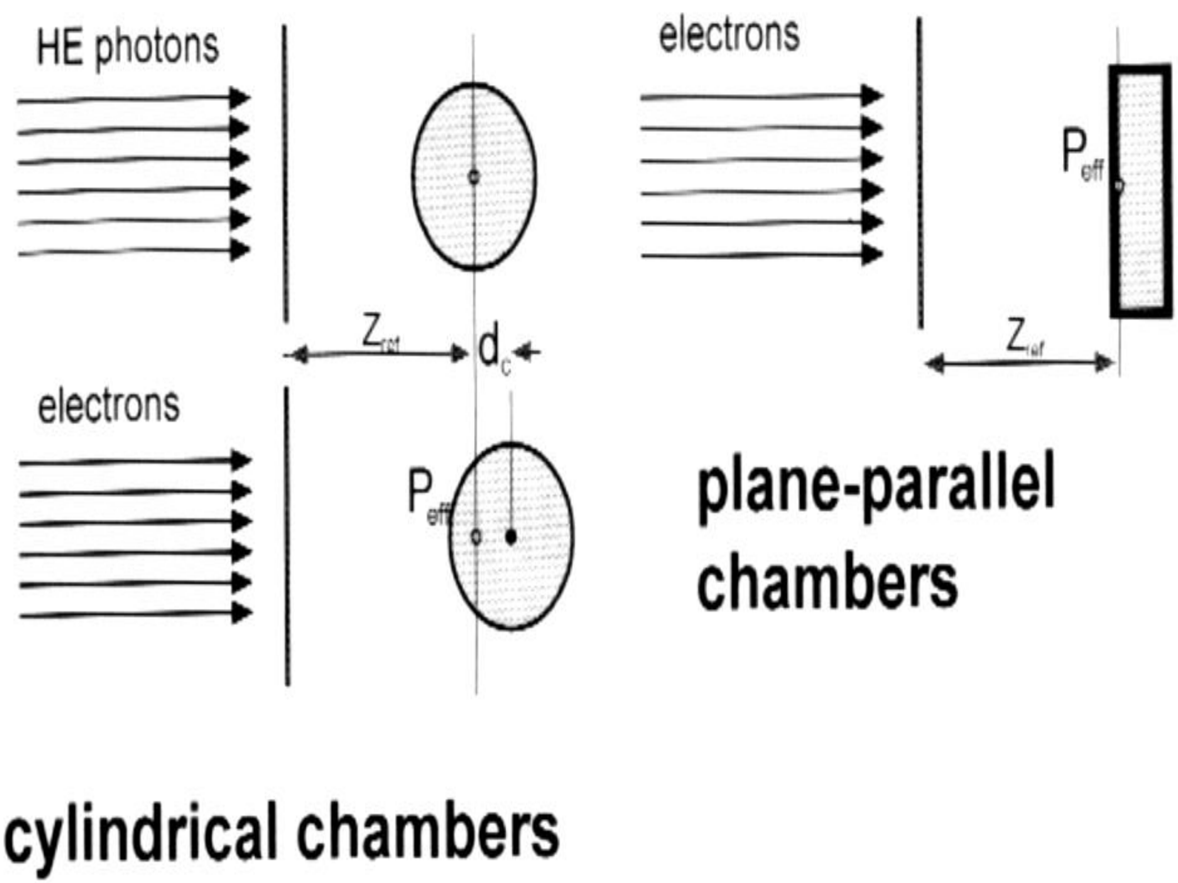
$$TPR_{20,10}$$

$$= 1.2661\, PDD_{20,10} - 0.0595$$

İyon odasının referans noktası

- Silindirik : İyon odasının merkezi
- Paralel düzlem : Hava kavitesinin önü

Reference point of measurement

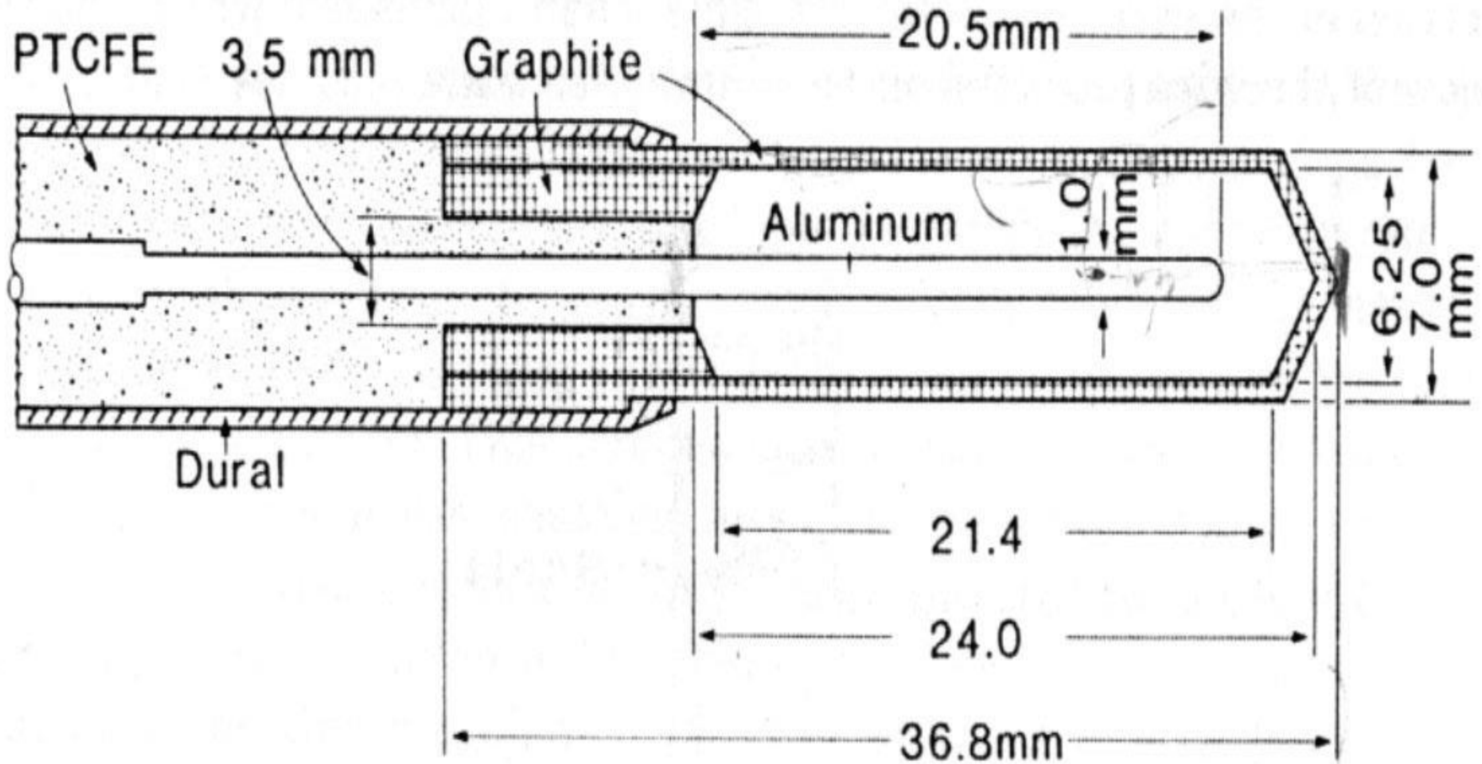


k_{Q,Q_o} için tavsiyeler

❶ Kullanıcı iyon odası için k_{Q,Q_o} 'ın doğrudan ölçülebilir

❷ Q_o olarak ^{60}Co ile hesaplanan k_Q günümüzde en genel pratik olandır

❸ Geniş kapsamlı deneysel değerlerden iyon odalarının geniş bir örneği yalnız standart laboratuvarlar tarafından bulunan k_{Q,Q_o} değerleri kullanılabilir. Standart laboratuvarlarda bulunmamışsa tavsiye edilmez.



Farmer Graphite/aluminum iyon odası 0.6 cc

TABLE II. CHARACTERISTICS OF CERTAIN IONIZATION CHAMBERS USED IN RADIOTHERAPY DOSIMETRY

	Internal length (mm)	Internal radius (mm)	Wall material	t_{wall} $g \cdot cm^{-2}$	Cap material	t_{cap} $g \cdot cm^{-2}$
CAPINTEC 0.07 cm^3 PR-05P minichamber	6.0	2.0	C-552	0.210	Polystyrene	0.568
CAPINTEC 0.14 cm^3 PR-05 minichamber	12.0	2.0	C-552	0.210	Polystyrene	0.568
CAPINTEC 0.65 cm^3 PR-06C Farmer type	22.0	3.2	C-552	0.050	C-552	0.924
CAPINTEC 0.65 cm^3 PR-06C Farmer type	22.0	3.2	C-552	0.050	Polystyrene	0.539
CAPINTEC 0.65 cm^3 PR-06C Farmer type	22.0	3.2	C-552	0.050	PMMA	0.547
CAPINTEC 0.60 m^3 (from AAPM)	23.8	3.25	Graphite	0.046	PMMA	0.625
EXRADIN 0.5 cm^3 Al (2 mm cap)	9.7	4.7	C-552	0.182	C-552	0.356
EXRADIN 0.5 cm^3 Al (4 mm cap)	9.7	4.7	C-552	0.182	C-552	0.712
EXRADIN 0.5 cm^3 T2	9.7	4.7	A-150	0.115	A-150	0.450
EXRADIN 0.05 cm^3 T1 min Shonka	7.2	2.0	A-150	0.117	A-150	0.450
FZS 0.4 cm^3 TK01 waterproof	12.0	3.5	Delrin	0.071	Delrin	0.430
FAR WEST TECH 0.1 cm^3 IC-18	9.5	2.3	A-150	0.183	A-150	0.386
NE 0.20 cm^3 2515	7.0	2.95	Tufnol	0.074	PMMA	0.543
NE 0.20 cm^3 2515/3	7.0	3.15	Graphite	0.0655	PMMA	0.543
NE 0.20 cm^3 2577	8.3	3.15	Graphite	0.0655	Delrin	0.5515
NE 0.60 cm^3 Farmer 2505 '54-'59[a]	24.0	2.95	Tufnol	0.075	PMMA	0.415
NE 0.60 cm^3 Farmer 2505 '59-'67[a]	24.0	2.95	Tufnol	0.075	PMMA	0.545
NE 0.60 cm^3 Farmer 2505/A '67-'74[a]	24.0	2.95	Nylon 66	0.063	PMMA	0.545

TABLE II (cont.)

	Internal length (mm)	Internal radius (mm)	Wall material	t_{wall} $g \cdot cm^{-2}$	Cap material	t_{cap} $g \cdot cm^{-2}$
NE 0.60 cm^3 Farmer 2505/3, 3A '71–'79[a]	24.0	3.15	Graphite	0.065	PMMA	0.551
NE 0.60 cm^3 Farmer 2505/3, 3B '74-present[a]	24.0	3.15	Nylon 66	0.041	PMMA	0.551
NE 0.60 cm^3 Guarded Farmer 2571	24.0	3.15	Graphite	0.065	Delrin	0.551
NE 0.60 cm^3 Robust Farmer 2581	24.0	3.15	A-150	0.040	PMMA	0.584
NE 0.60 cm^3 Robust Farmer 2581 (polystyrene cap)	24.0	3.15	A-150	0.0407	Polystyrene	0.584
NE 0.325 cm^3 NPL Sec Std 2561	9.2	3.7	Graphite	0.090	Delrin	0.600
PTW 0.6 cm^3 23333 (3 mm cap)	21.9	3.05	PMMA	0.059	PMMA	0.356
PTW 0.6 cm^3 23333 (4.6 mm cap)	21.9	3.05	PMMA	0.053	PMMA	0.551
PTW 0.4 cm^3 233331	21.9	2.35	PMMA	0.142	PMMA	0.551
PTW 0.3 cm^3 Normal M233332	18.0	2.5	PMMA	0.059	PMMA	0.356
PTW 1 cm^3 Transit M233331	22.0	4.0	PMMA	0.059	PMMA	0.356
PTW 0.3 cm^3 Waterpr M2333641	15.1	2.75	PMMA	0.089	PMMA	0.356
VICTOREEN 0.1 cm^3 Radocon II 555	4.3	2.5	Delrin	0.529		
VICTOREEN 0.3 cm^3 Radocon III	23.0	2.4	Polystyrene	0.117	PMMA	0.481
VICTOREEN 0.30 cm^3 30-348	18.0	2.5	PMMA	0.06	PMMA	0.36
VICTOREEN 0.60 cm^3 30-351	23.0	3.05	PMMA	0.06	PMMA	0.36
VICTOREEN 1.00 cm^3 30-349	22.0	4.0	PMMA	0.06	PMMA	0.36
SSI Graphite	17.9	4.0	Graphite	0.084	Graphite	0.384
SSI A-150	17.9	4.0	A-150	0.056	A-150	0.373

[a] Year of manufacture.

TABLE 5. CHARACTERISTICS OF PLANE PARALLEL CHAMBER TYPES FOR MEGAVOLTAGE PHOTON AND ELECTRON BEAMS *(adapted from Ref. [10])*

Ionization chamber type	Materials	Window thickness	Electrode spacing	Collecting electrode diameter	Guard ring width
Exradin A10 Markus type chamber	Kapton window C-552 body	3.86 mg/cm^2 0.05 mm	2 mm	5.4 mm	4.3 mm
Exradin 11[a] Roos type chamber	Wall and electrode in model P11: polystyrene equiv. model A11: C-552	1 mm polystyrene (P11) C-552 (A11)	2 mm	20 mm	4.4 mm
IBA PPC05	C-552 window and body Graphited (PEEK[b]) electrode	176 mg/cm^2 1 mm	0.5 mm	10 mm	3.5 mm
IBA PPC40 Roos type chamber	PMMA and graphite window Graphited electrode	118 mg/cm^2 1 mm	2 mm	16 mm	4 mm
IBA NACP	Mylar foil and graphite window, PMMA body Graphited electrode	104 mg/cm^2 0.6 mm	2 mm	10 mm	3 mm
PTW 34001 Roos type chamber	PMMA and graphite window Graphited electrode	132 mg/cm^2 1.13 mm	2 mm	16 mm	4 mm

TABLE 5. CHARACTERISTICS OF PLANE PARALLEL CHAMBER TYPES FOR MEGAVOLTAGE PHOTON AND ELECTRON BEAMS *(adapted from Ref. [10])* (cont.)

Ionization chamber type	Materials	Window thickness	Electrode spacing	Collecting electrode diameter	Guard ring width
PTW 34045 Advanced Markus type chamber	Polyethylene foil window PMMA cap, PMMA body	106 mg/cm^2 1.3 mm (incl. cap)	1 mm	5 mm	2 mm
PTW 23343[c] Markus type chamber	Polyethylene foil window PMMA cap, PMMA body	106 mg/cm^2 1.3 mm (incl. cap)	2 mm	5.3 mm	0.2 mm
Sun Nuclear SNC350p Roos type chamber	PMMA and graphite window Graphited electrode	n.a.[d]	2 mm	15.6 mm	4.1 mm

[a] Exradin T11 is no longer recommended because of the hygroscopic nature of A-150 plastic.

[b] Polyetheretherketone ($C_{19}H_{18}O_3$) 1.265 g/cm^3.

[c] The PTW 23343 (Markus) chamber is included here, despite having a narrower guard ring than specified in Section 4.2.1, as it is still commonly used for a range of beam modalities and applications.

[d] n.a.: not applicable

TABLE 4. CHARACTERISTICS OF PLANE-PARALLEL CHAMBER TYPES *(adapted from Ref. [21])*

Ionization chamber type[a]	Materials	Window thickness	Electrode spacing	Collecting electrode diameter	Guard ring width	Recommended phantom material
NACP01 (Scanditronix) Calcam-1 (Dosetek)	Graphite window, graphited rexolite electrode, graphite body (back wall), rexolite housing	90 mg/cm^2 0.5 mm	2 mm	10 mm	3 mm	Polystyrene Graphite Water (with water-proof housing)
NACP02 (Scanditronix) Calcam-2 (Dosetek)	Mylar foil and graphite window, graphited rexolite electrode, graphite body (back wall), rexolite housing	104 mg/cm^2 0.6 mm	2 mm	10 mm	3 mm	Water, PMMA
Markus chamber PTW 23343 NA 30-329 NE 2534	Graphited polyethylene foil window, graphited polystyrene collector, PMMA body, PMMA cap	102 mg/cm^2 0.9 mm (incl. cap)	2 mm	5.3 mm	0.2 mm	Water, PMMA
Scdx-Wellhöfer PPC 05	Window and body C-552, graphited (PEEK[b]) electrode	176 mg/cm^2 1 mm	0.5 mm	10 mm	3.5 mm	Water
Holt chamber (Memorial) NA 30-404	Graphited polystyrene wall and electrode, polystyrene body	416 mg/cm^2 4 mm	2 mm	25 mm	5 mm	Polystyrene (phantom integr.)

TABLE 4. (cont.)

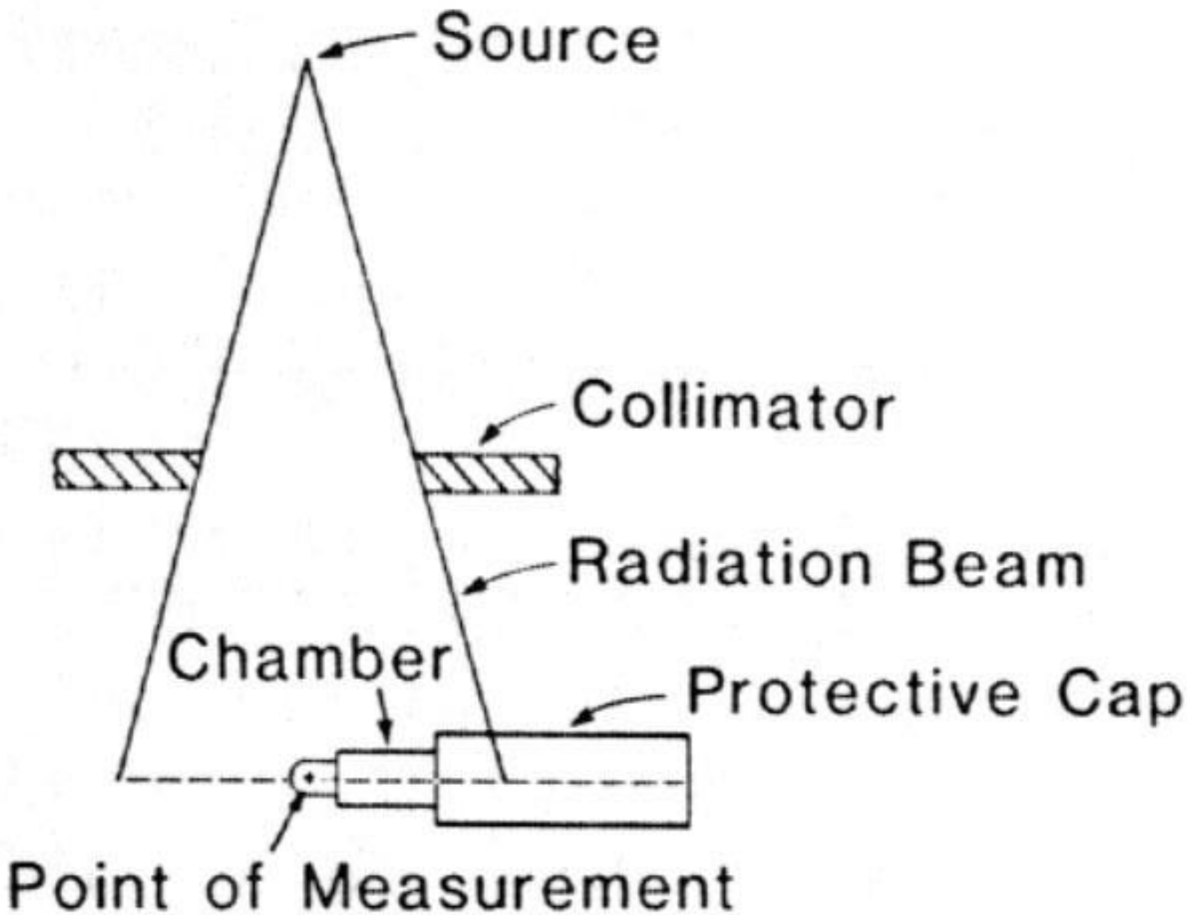
Capintec PS-033	Aluminized mylar foil window, carbon impregnated air equivalent, plastic electrode, polystyrene body	0.5 mg/cm^2 0.004 mm	2.4 mm	16.2 mm	2.5 mm	Polystyrene
Exradin 11	Conducting plastic wall and electrodes Model P11: polystyrene equivalent Model A11: C-552, air equivalent Model T11: A-150, tissue equivalent	P11: 104 mg/cm^2 1 mm	2 mm	20 mm	5.1 mm	P11: polystyrene water
Roos chamber PTB FK6 PTW 34001 Scdx-Wellhöfer PPC 35 Scdx-Wellhöfer PPC 40	PMMA, graphited electrodes	118 mg/cm^2 1 mm	2 mm	16 mm	4 mm	Water PMMA
Attix chamber RMI 449	Kapton conductive film window, graphited polyethylene collector, solid water body	4.8 mg/cm^2 0.025 mm	1 mm (0.7 mm reported)	12.7 mm	13.5 mm	Solid water

[a] Some of the chambers listed in this table fail to meet the minimum requirements described in Section 4.2.1. However, they have been included because of their current clinical use.

[b] Polyetheretherketone ($C_{19}H_{18}O_3$) 1.265 g/cm^3.

Radyasyon Demet Geometrisi

- Demet hizası ve konumu;
  - Kolimatör dönme ekseni
  - Geometrik demet ekseni
  - Radyasyon demet ekseni
  - Işık demet ekseni


Source
Collimator
Radiation Beam
Chamber
Protective Cap
Point of Measurement

Suda soğurulan dozun belirlenmesi

- Polarite Etkisi : İyon odasının polarite etkisi, özellikle paralel düzlem iyon odaları için kontrol edilmelidir ve Tablo I'de verilen limitler içinde bulunmalıdır. Bu etki, düşük enerjili elektronlar için büyük olabilir. Pratikte genellikle yalnız bir polarite kullanılır.

☞ $$M = \frac{|M_+| + |M_-|}{2}$$

Suda soğurulan dozun belirlenmesi

- Rekombinasyon düzeltme faktörü P_s'yi belirlemek için deneysel bir yöntem tavsiye edilir. "İki-voltaj" yöntemi olarak adlandırılan yöntem basittir. Bu yöntem aynı ışınlama koşulları için kullanılan 2 farklı V_1 (normal çalışma bias voltajı) ve V_2 voltajları için toplanan Q_1 ve Q_2 yüklerinin ölçümüne dayanır.
- V_1 normal çalışma bias voltajında puls ve puls taramalı radyasyon için;

☞ $$P_s = a_o + a_1\left(\frac{Q_1}{Q_2}\right) + a_2\left(\frac{Q_1}{Q_2}\right)^2$$

- Burada a_i sabitleri, Tablo VIII ve IX'dan bulunabilir. Sürekli radyasyon için P_s şekil 13'te verilmiştir.

TABLE VIII. QUADRATIC FIT COEFFICIENTS FOR PULSED RADIATION AS A FUNCTION OF THE VOLTAGE RATIO V_1/V_2

These coefficients are used to calculate p_s by the two-voltage technique using $p_s = a_0 + a_1(Q_1/Q_2) + a_2(Q_1/Q_2)^2$. (From Weinhous and Meli [74])

Voltage ratio	a_0	a_1	a_2
2.0	2.337	−3.636	2.299
2.5	1.474	−1.587	1.114
3.0	1.198	−0.8753	0.6773
3.5	1.080	−0.5421	0.4627
4.0	1.022	−0.3632	0.3413
5.0	0.9745	−0.1875	0.2135
6.0	0.9584	−0.1075	0.1495
8.0	0.9502	−0.03732	0.08750
10.0	0.9516	−0.01041	0.05909

TABLE IX. QUADRATIC FIT COEFFICIENTS FOR PULSED SCANNED RADIATION AS A FUNCTION OF VOLTAGE RATIO V_1/V_2

These coefficients are used to calculate p_s by the two-voltage technique using $p_s = a_0 + a_1(Q_1/Q_2) + a_2(Q_1/Q_2)^2$. (From Weinhous and Meli [74])

Voltage ratio	a_0	a_1	a_2
2.0	4.711	−8.242	4.533
2.5	2.719	−3.977	2.261
3.0	2.001	−2.402	1.404
3.5	1.665	−1.647	0.9841
4.0	1.468	−1.200	0.7340
5.0	1.279	−0.7500	0.4741
6.0	1.177	−0.5081	0.3342
8.0	1.089	−0.2890	0.2020
10.0	1.052	−0.1896	0.1398

TABLE 10. QUADRATIC FIT COEFFICIENTS FOR THE CALCULATION OF k_s BY THE TWO VOLTAGE TECHNIQUE IN PULSED AND PULSED–SCANNED RADIATION AS A FUNCTION OF THE VOLTAGE RATIO V_1/V_2 [117]

V_1/V_2	Pulsed			Pulsed–scanned		
	a_0	a_1	a_2	a_0	a_1	a_2
2.0	2.337	−3.636	2.299	4.711	−8.242	4.533
2.5	1.474	−1.587	1.114	2.719	−3.977	2.261
3.0	1.198	−0.875	0.677	2.001	−2.402	1.404
3.5	1.080	−0.542	0.463	1.665	−1.647	0.984
4.0	1.022	−0.363	0.341	1.468	−1.200	0.734
5.0	0.975	−0.188	0.214	1.279	−0.750	0.474

subsequently only at voltages within the linear range, in which case the use of the two voltage method is valid, taking into account the requirements about recombination given in Table 3.

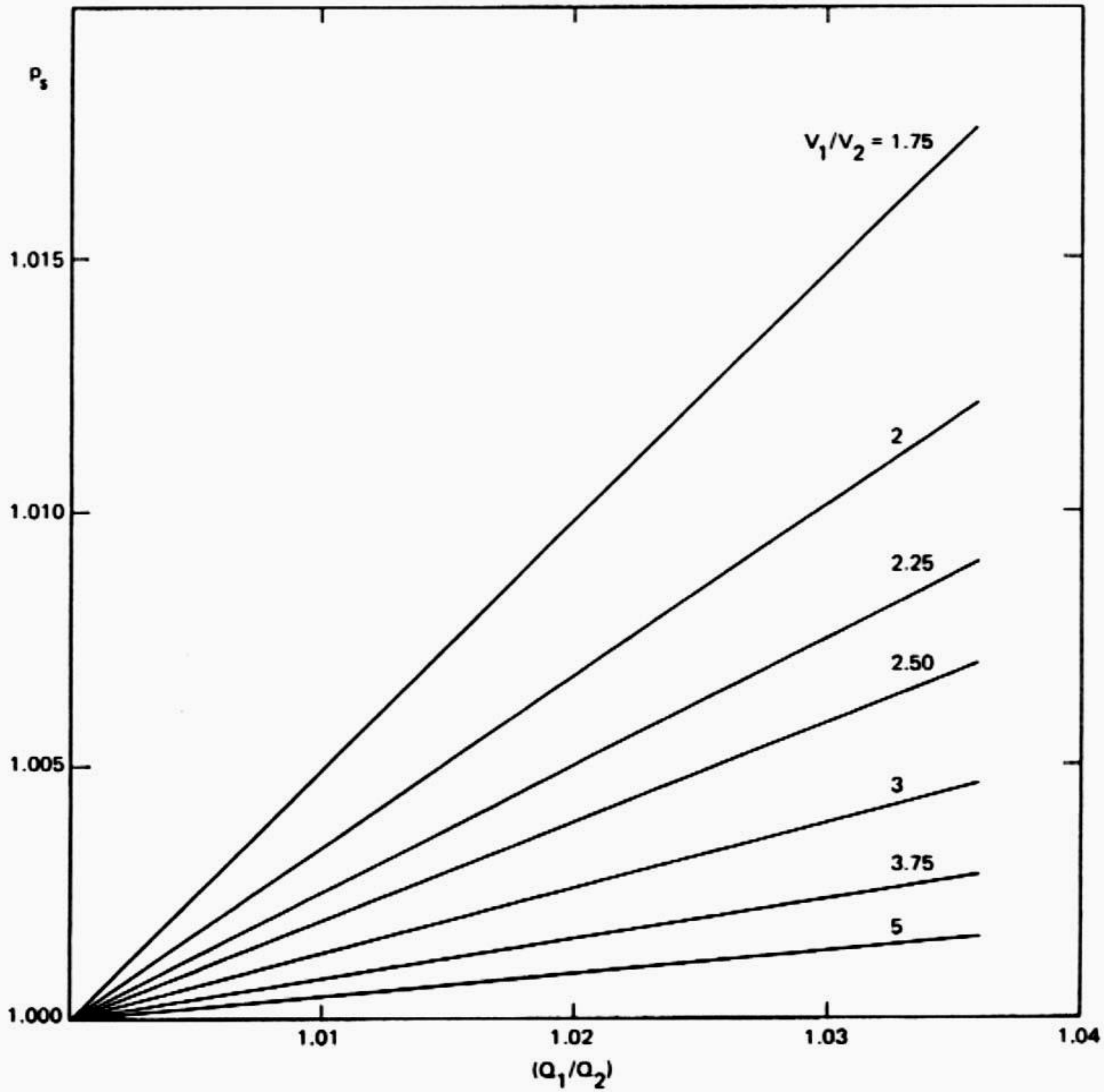


FIG. 13. The correction factor for recombination p_s in continuous radiation beams (from SEFM [9]). The 'two-voltage' method is used to determine the ratio of collected charges (or electrometer readings) Q_1/Q_2 (see text).

TABLE 11. GENERIC VALUES FOR THE VOLUME AVERAGING CORRECTION FACTOR IN FLATTERING FILTER FREE BEAMS OF CLINICAL ACCELERATORS

Cavity length, L (cm)	Beam quality index, $TPR_{20,10}$					
	0.6	0.63	0.66	0.69	0.72	0.75
0.5	1.000	1.000	1.000	1.000	1.000	1.000
1.0	1.000	1.000	1.000	1.001	1.001	1.001
1.5	1.000	1.001	1.001	1.001	1.002	1.002
2.0	1.000	1.001	1.002	1.002	1.003	1.004
2.5	1.001	1.002	1.003	1.004	1.005	1.006

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- İyon odaları: Yüksek enerjili foton demetlerinde referans dozimetri için yalnız silindirik iyon odaları tavsiye edilir.
- Fantomlar: Referans fantom sudur. Yatay demetlerde fantom penceresi 0.2 - 0.5 cm kalınlığında plastik olmalıdır. İyon odası pozisyonlanırken pencerenin su eşdeğeri kalınlığı hesaba katılmalıdır.($t_{win}\, d_{pl}$) ; d_{PMMA} =1.19 g/cm^3 $d_{polystrene}$ = 1.06 g/cm^3

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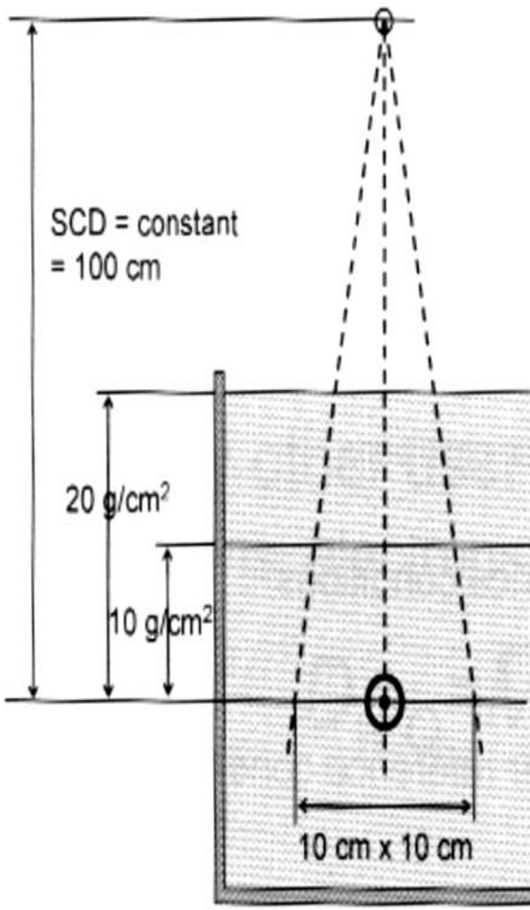
Foton demet kalitesi tayini referans koşulları

- Fantom materyali : su
- İyon odası tipi :silindirik veya paralel düzlem
- Ölçüm derinlikleri : 20 g/cm^2 ve 10 g/cm^2
- İyon odasının referans noktası: silindirik iyon odası için merkezi eksen üzerinde kavite hacminin merkezinde ; paralel düzlem için merkezi eksen üzerinde pencerenin iç yüzeyinde
- İyon odası referans noktası konumu SCD: 100 cm
- SCD de alan: 10 cm x 10 cm

Beam Quality: determination of $TPR_{20,10}$



$\Rightarrow M_{10}$

$\Rightarrow M_{20}$

$$TPR_{20,10} = \frac{D_{20}}{D_{10}} \approx \frac{M_{20}}{M_{10}}$$

Demet Kalite Spesifikasyonu

- Demet Kalitesi ($TPR_{20,10}$'nun belirlenmesi):

☞ $$TPR_{20,10} = \frac{D_{20}}{D_{10}} \approx \frac{M_{20}}{M_{10}}$$

↳SCD = sabit = 100 cm

↳d_2= 20 g / cm^2

↳d_1 = 10 g / cm^2

↳Alan = 10 cm x 10 cm (SCD = 100 cm'de)

TRS 398
Yüksek enerjili Foton demetlerinde **suda soğurulan doz** tayini referans koşulları

- Fantom materyali :su   İyon odası tipi: Silindirik
- Ölçüm derinliği z_{ref} :

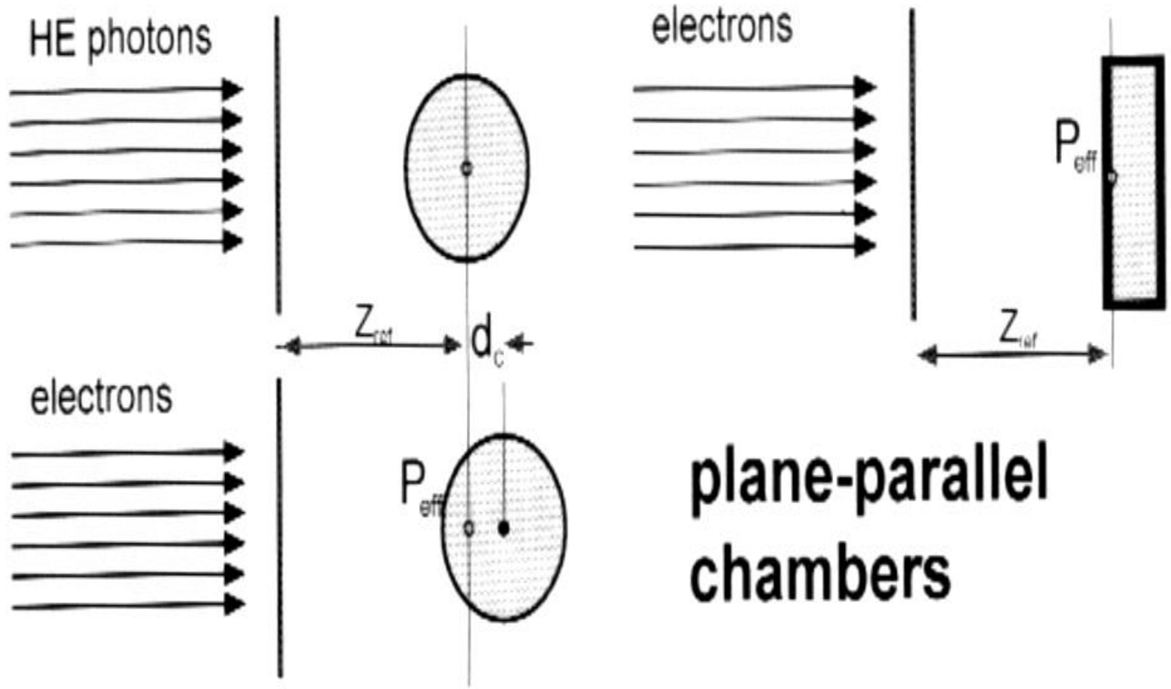
  TPR 20,10 <0.7   10 g / cm^2(veya 5 g / cm^2)

  TPR 20,10 ≥0.7   10 g / cm^2
- İyon odasının referans noktası: Merkezi eksen üzerinde kavite hacminin merkezinde
- İyon odasının referans noktasının konumu: ölçüm derinliği olan zref
- SSD/SCD   100 cm ; Alan boyutu: 10cmX10 cm

İyon odasının referans noktası

- Silindirik : İyon odasının merkezi
- Paralel düzlem : Hava kavitesinin önü

Reference point of measurement



plane-parallel chambers

cylindrical chambers

k_{Q,Q_o} için tavsiyeler

❶ Kullanıcı iyon odası için k_{Q,Q_o} 'ın doğrudan ölçülebilir

❷ Q_o olarak ^{60}Co ile hesaplanan k_Q günümüzde en genel pratik olandır

❸ Geniş kapsamlı deneysel değerlerden iyon odalarının geniş bir örneği yalnız standart laboratuvarlar tarafından bulunan k_{Q,Q_o} değerleri kullanılabilir. Standart laboratuvarlarda bulunmamışsa tavsiye edilmez.

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$$k_{Q,Q_0} = \frac{N_{D,w,Q}}{N_{D,w,Q_0}}$$

Referans kalite Q_0 Co-60 ise ,

$$k_{Q,Q_0} = k_Q$$

$$N_{D,w,Q_0} = N_{D,w}$$

$Q_o = 6\,MV$

$Q_{int} = {}^{60}Co$ γ ışınları

$Q = 18\,MV$

$${}_{18MV,\,6MV} = \frac{N_{D,w,18MV}}{N_{D,w,6MV}} = \frac{N_{D,w,18MV}}{N_{D,w,{}^{60}Co}} \frac{N_{D,w,{}^{60}Co}}{N_{D,w,6MV}}$$

$$= \frac{k_{18MV,{}^{60}Co}}{k_{6MV,{}^{60}Co}} = \frac{k_{18MV}}{k_{6MV}}$$

TRS-398

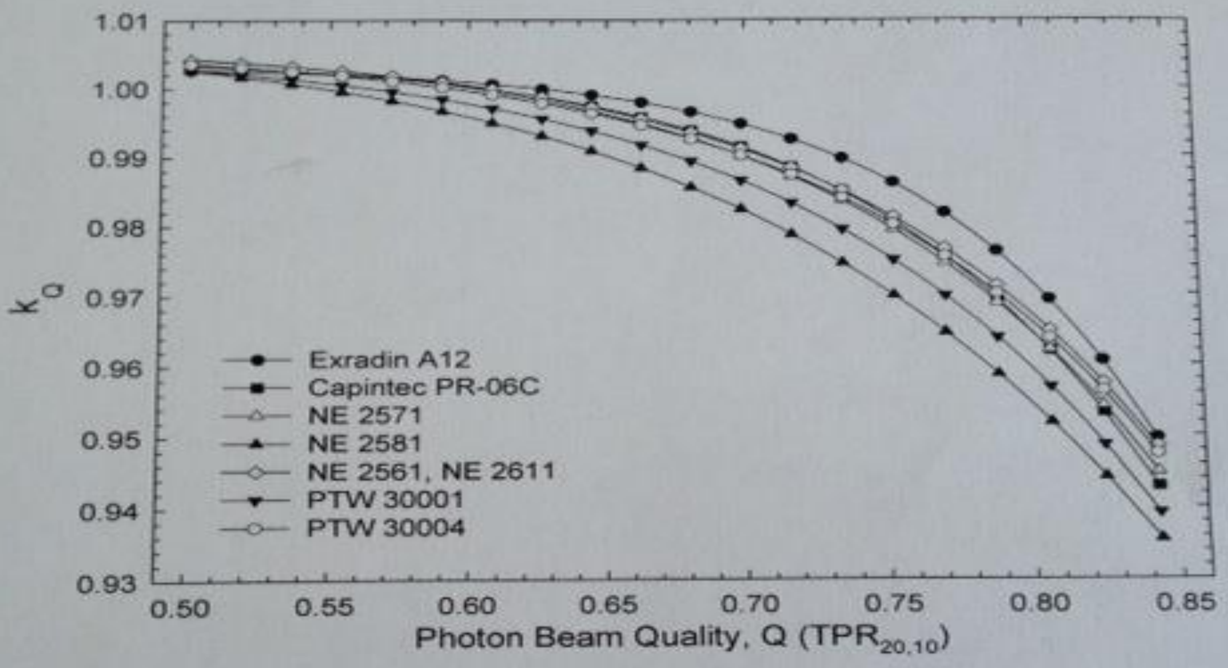

Fig. 6.2. Sigmoidal fits of calculated values of k_Q for various cylindrical ionization chambers commonly used for reference dosimetry, as a function of photon beam quality Q ($TPR_{20,10}$). Open symbols correspond to graphite-walled ionization chambers, solid symbols to plastic-walled chambers. Data from Table 6.III.

6.9. Worksheet

Determination of the absorbed dose to water in a high-energy photon beam

User: ______________________ Date: ______________________

1. Radiation treatment unit and reference conditions for $D_{w,Q}$ determination

Accelerator: ______________ Nominal Acc Potential: __________ MV

Nominal dose rate: __________ MU min^{-1} Beam quality, Q ($TPR_{20,10}$): __________

Reference phantom: water Set up: ☐ SSD ☐ SAD

Reference field size: 10x10 cm x cm Reference distance (cm): __________

Reference depth z_{ref}: __________ g cm^{-2}

2. Ionization chamber and electrometer

Ionization chamber model: ______________ Serial no.: __________

Chamber wall material: __________ thickness: __________ g cm^{-2}

Waterproof sleeve material: __________ thickness: __________ g cm^{-2}

Phantom window material: __________ thickness: __________ g cm^{-2}

Absorbed-dose-to-water calibration factor [a] N_{D,w,Q_o} = __________ ☐ Gy nC^{-1} ☐ Gy rdg^{-1}

Calibration quality Q_o: ☐ ^{60}Co ☐ photon beam Calibration depth: __________ g cm^{-2}

If Q_o is photon beam, give $TPR_{20,10}$: __________

Reference conditions for calibration P_o: __________ kPa T_o: __________ °C Rel. humidity: __________ %

Polarizing potential V_1: ______ V Calibration polarity: ☐ +ve ☐ −ve ☐ corrected for polarity effect

User polarity: ☐ +ve ☐ −ve

Calibration laboratory: ______________________ Date: ______________________

Electrometer model: ______________________ Serial no.: ______________________

Calibrated separately from chamber: ☐ yes ☐ no Range setting: __________

If yes Calibration laboratory: ______________________ Date: __________

3. Dosimeter reading [b] and correction for influence quantities

Uncorrected dosimeter reading at V_1 and user polarity: __________ ☐ nC ☐ rdg

Corresponding accelerator monitor units: __________ MU

Ratio of dosimeter reading and monitor units: M_1 = __________ ☐ nC MU^{-1} ☐ rdg MU^{-1}

(i) Pressure P: __________ kPa Temperature T: __________ °C Rel. humidity (if known): __________ %

$$k_{TP} = \frac{(273.2 + T)}{(273.2 + T_o)} \frac{P_o}{P} = \text{\_\_\_\_\_\_\_\_\_\_}$$

(ii) Electrometer calibration factor [c] k_{elec}: ☐ nC rdg^{-1} ☐ dimensionless k_{elec} = __________

(iii) Polarity correction [d] rdg at $+V_1$: M_+ = __________ rdg at $-V_1$: M_- = __________

$$k_{pol} = \frac{|M_+| + |M_-|}{2M} = \text{\_\_\_\_\_\_\_\_\_\_}$$

(iv) Recombination correction (two-voltage method)

Polarizing voltages: V_1 (normal) = ________ V V_2 (reduced) = ________ V

Readings* at each V: M_1 = ________ M_2 = ________

Voltage ratio V_1 / V_2 = ________ Ratio of readings M_1 / M_2 = ________

Use Table 4.VII for a beam of type: ☐ pulsed ☐ pulsed-scanned

a_0 = ________ a_1 = ________ a_2 = ________

$$k_s = a_0 + a_1\left(\frac{M_1}{M_2}\right) + a_2\left(\frac{M_1}{M_2}\right)^2 = \_\_\_\_\_\_\_\_$$

Corrected dosimeter reading at the voltage V_1:

$$M_Q = M_1\, k_{TP}\, k_{elec}\, k_{pol}\, k_s = \_\_\_\_\_\_\_\_ \quad ☐\ \text{nC MU}^{-1} \quad ☐\ \text{rdg MU}^{-1}$$

4. Absorbed dose to water at the reference depth, z_{ref}

Beam quality correction factor for user quality Q: k_{Q,Q_o} = ________

taken from ☐ Table 6.III ☐ Other, specify: ________

$$D_{w,Q}(z_{ref}) = M_Q N_{D,w,Q_o} k_{Q,Q_o} = \_\_\_\_\_\_\_\_ \text{ Gy MU}^{-1}$$

5. Absorbed dose to water at the depth of dose maximum, z_{max}

Depth of dose maximum: z_{max} = ________ g cm^{-2}

(i) SSD set-up

Percentage depth-dose at z_{ref} for a 10 cm x 10 cm field size: PDD (z_{ref}= ____ g cm^{-2}) = ________ %

Absorbed-dose calibration of monitor at z_{max}:

$$D_{w,Q}(z_{max}) = 100\, D_{w,Q}(z_{ref}) / PDD(z_{ref}) = \_\_\_\_\_\_\_\_ \text{ Gy MU}^{-1}$$

(ii) SAD set-up

TMR at z_{ref} for a 10 cm x 10 cm field size: TMR (z_{ref}= ____ g cm^{-2}) = ________

Absorbed-dose calibration of monitor at z_{max}:

$$D_{w,Q}(z_{max}) = D_{w,Q}(z_{ref}) / TMR(z_{ref}) = \_\_\_\_\_\_\_\_ \text{ Gy MU}^{-1}$$

Note that if Q_o is ^{60}Co, N_{D,w,Q_o} is denoted by $N_{D,w}$.

All readings should be checked for leakage and corrected if necessary.

If the electrometer is not calibrated separately set $k_{elec} = 1$.

M in the denominator of k_{pol} denotes reading at the user polarity. Preferably, each reading in the equation should be the average of the ratios of M (or M_+ or M_-) to the reading of an external monitor, M_{em}.

It is assumed that the calibration laboratory has performed a polarity correction. Otherwise k_{pol} is determined according to

rdg at $+V_1$ for quality Q_o: M_+ = ________ rdg at $-V_1$ for quality Q_o: M_- = ________

$$k_{pol} = \frac{\left[(|M_+| + |M_-|)/M\right]_Q}{\left[(|M_+| + |M_-|)/M\right]_{Q_o}} = \_\_\_\_\_\_\_\_$$

Strictly, readings should be corrected for polarity effect (average with both polarities). Preferably, each reading in the equation should be the average of the ratios of M_1 or M_2 to the reading of an external monitor, M_{em}.

It is assumed that the calibration laboratory has performed a recombination correction. Otherwise the factor $k_s' = k_s / k_{s,Q_o}$ should be used instead of k_s. When Q_o is ^{60}Co, k_{s,Q_o} (at the calibration laboratory) will normally be close to unity and the effect of not using this equation will be negligible in most cases.

* Check that $k_s - 1 \approx \dfrac{M_1/M_2 - 1}{V_1/V_2 - 1}$

Note that if Q_o is ^{60}Co, k_{Q,Q_o} is denoted by k_Q, as given in Table 6.III.

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AB-0073-K
MTR-70
100
01-12

SEKONDER STANDART DOZİMETRİ LABORATUVARI

24.01.2012 • 0424

Kalibrasyon Sertifikası
Calibration Certificate

		Tedavi Dozimetresi / *Therapy Dosemeter*		
Makine/Cihaz *Instrument/Device*	:	**Elektrometre**/*Electrometer*	**İyon Odası**/*Ionization Chamber*	
İmalatçı / *Manufacturer*	:	PTW	PTW	
Tip /*Type*	:	UNIDOS E	TM30013	
Seri Numarası *Serial Number*	:	80793	4825	
Hassasiyet (N) *Sensitivity*	:	5,340E+07 Gy/C	**Yüksek Gerilim (V):** *High Voltage*	(+) 400 V

İyon Odasının Atmosfere Açıklığı *Air Venting of Ionization Chamber* : ☑ Atmosfere Açık/Unsealed ☐ Atmosfere Kapalı/Sealed

Cihazın Laboratuvara Kabul Tarihi / *Date of Receipt of Device* : 18.01.2012

Prosedür/*Procedure*
Bu sertifikada, "IAEA TRS-398 Code of Practice" dokümanında tanımlanan yönteme göre Suda Absorblanan Doz kalibrasyon faktörü ($N_{D,w}$) verilmektedir.
Absorbed Dose to Water calibration factor ($N_{D,w}$) is given according to the method described in the document of "IAEA TRS-398 Code of Practice".

Referans Dozimetre/*Reference Dosemeter*
Elektrometre /*Electrometer* : Wellhöfer Dose1, SN: 7967
İyon odası/*Ionization chamber* : PTW 30001, SN: 1418

Ölçüm Şartları/*Measurement Conditions*
Ölçüm Aralığı/*Measuring Range* Dose : Med 653 mGy/s Charge : Med 12,2 nA

Geometrik Şartlar/*Geometrical Conditions*

Fantom boyutu *Phantom size*	:	30x30x30 cm^3	Fantom malzemesi *Phantom material*	:	Su *Water*
Kaynak fantom yüzeyi mesafesi *Source to phantom surface distance*	:	95 cm	Fantom derinliği *Depth of phantom material*	:	5 gr/cm^2
Referans nokta *Reference point*	:	İyon odası merkezi *Center of ion. cham.*	Alan boyutu *Field size*	:	10x10 cm^2

İklimsel Şartlar/*Climatic Conditions*

Referans sıcaklık T_0 *Reference temperature*	:	20,0 °C	Sıcaklık aralığı *Range of temperature*	:	18,7	18,7
Referans basınç P_0 *Reference pressure*	:	1013,25 mbar (760 mmHg)	Basınç aralığı *Range of pressure*	:	1024,03	1024,03
Referans bağıl nem *Reference humidity*	:	% 50 ± 20	Bağıl nem (%) *Rel. humidity*	:	32	32

Sızıntı Testi / *Leakage Test* : 0,0000 nC/dk. (Kalibrasyon doz verisinin % 0,1 değerinden düşüktür)

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SEKONDER STANDART DOZİMETRİ LABORATUVARI

24.01.2012 • 0424

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Kalibrasyon Sertifikası
Calibration Certificate

Ölçüm Sonuçları
Measurement Results

Suda Absorblanan Doz Kalibrasyon Faktörü
Absorbed Dose to Water Calibration Factor

Radyasyon /*Radiation*	N_{DW} mGy/mGy	N_{DW} mGy/nC	U (*) %
Co-60	1,003	53,539	0,6

Radyasyon Doz Hızı : 389,550 mGy/dk.
Beam Dose Rate

Kalibrasyonda yer değiştirme metodu uygulanmıştır. Kalibrasyon faktörü N_{DW}, SSDL çalışma standardının atmosferik şartlara göre normalize edilen okuma değeri ("mGy"), müşteri dozimetresiyle alınan okumaların atmosferik şartlara göre normalize edilmiş okuma değerine (mGy veya nC) oranıdır. Referans standardın izlenebilirliği Physicalish -Technische Bundesanstalt tarafından sağlanmaktadır. Su fantomundaki ölçümler su geçirmez aparat ile alınmıştır. Her iki dozimetre kalibrasyon öncesinde 5 Gy'lik ön ışınlamaya tabi tutulmuştur.

Substition method is used for the calibration. The calibration factor, N_{DW} is the ratio of the conventional true value of the quantity to be measured ("mGy") to the indication of the instrument to be tested (mGy or nC). Traceability of the reference standard was performed by Physikalisch - Technische Bundesanstalt (PTB) Germany. The measurements in the water phantom are taken by ionization chamber within waterproof sleeve. Referans and user dosimiters were pre-irradiated to 5 Gy.

Ölçüm Belirsizliği
Measurement Uncertainty

Kalibrasyon faktöründeki belirsizlikler, IAEA-TECDOC-1585 numaralı doküman ile "Guide to The Expression of Uncertainty in Measurement" dokümanları esas alınarak hesaplanmıştır.
The uncertainty of calibration factor is calculated according to "IAEA-TECDOC-1585" and "Guide to The Expression of Uncertainity in Measurement".

(*) Beyan edilen genişletilmiş ölçüm belirsizliği, standart belirsizliğin, k=2 olarak alınan genişletme katsayısı ile çarpımı sonucunda bulunan değerdir ve yaklaşık %95 oranında güvenilirlik sağlamaktadır.
The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

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NUCLEAR ENERGY RESEARCH INSTITUTE
İKİNCİL STANDART DOZİMETRİ LABORATUVARI
SECONDARY STANDARD DOSIMETRY LABORATORY

TENMAK NÜKEN

TÜRKAK AB-0073-K 117850/003 03-24

KALİBRASYON SERTİFİKASI
CALIBRATION CERTIFICATE

Sayfa 1/3
Page 1 of 3

Cihazın Sahibi/Adresi *Customer / Address*	:	SBÜ. GÜLHANE EĞİTİM VE ARAŞTIRMA HASTANESİ RADYASYON ONKOLOJİSİ A.D.	
İstek Numarası *Order No.*	:	C240266	
Makine/Cihaz *Instrument/Device*	:	Tedavi Dozimetresi / *Therapy Dosemeter*	
		Elektrometre/*Electrometer*	İyon Odası/*Ionization Chamber*
İmalatçı *Manufacturer*	:	PTW UNIDOS webline	PTW
Tip *Type*	:	T10022	TW30013
Seri Numarası *Serial Number*	:	365	7358
Kalibrasyon Tarihi *Date of Calibration*	:	23.05.2024	
Sertifika Sayfa Sayısı *Number of Page of the Certificate*	:	3	

Bu kalibrasyon sertifikası, Uluslararası Birimler Sisteminde (SI) tanımlanmış birimleri realize eden ulusal ölçüm standartlarına izlenebilirliği belgeler.
This calibration certificate documents the traceability to national standards, which realize the unit of measurement according to the International System of Units (SI).

Kalibrasyon laboratuvarı olarak faaliyet gösteren, Nükleer Enerji Araştırma Enstitüsü, İkincil Standart Dozimetri Laboratuvarı, TÜRKAK'tan AB-0073-K dosya numarası ile TS EN ISO/IEC 17025:2017 standardına göre akredite edilmiştir.
Nuclear Energy Research Institute Secondary Standard Dosimetry Laboratory accredited by TÜRKAK under registration number AB-0073-K for TS EN ISO/IEC 17025:2017 as Calibration Laboratory"

Türk Akreditasyon Kurumu (TÜRKAK) kalibrasyon sertifikalarının tanınması konusunda Avrupa Akreditasyon Birliği (EA) ve Uluslararası Laboratuvar Akreditasyon Birliği (ILAC) ile karşılıklı tanınma antlaşmasını imzalamıştır.
The Turkish Accreditation Agency (TÜRKAK) is signatory to the multilateral agreements of the European co-operation for the Accreditation (EA) and of the International Laboratory Accreditation (ILAC) for the Mutual recognition of calibration certificates.

Ölçüm sonuçları, genişletilmiş ölçüm belirsizlikleri ve kalibrasyon metotları bu sertifikanın tamamlayıcı kısımları takip eden sayfalarda verilmiştir.
The measurements, the expanded uncertainties with confidence probability and calibration methods are given on the following pages which are part of this certificate.

Mühür *Seal*	23.05.2024 **Yayımlandığı Tarih** *Date* (Gün/Ay/Yıl)(Day/Month/Year)	Muharrem KORKMAZ **Kalibrasyonu Yapan** *Calibrated by*	Eylem İlker KEKEÇ **Onaylayan** *Approval*
		Tarih/Date : (Gün/Ay/Yıl)(Day/Month/Year)	23.05.2024

TENMAK
NÜKEN

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117050/005
05-24

KALİBRASYON SERTİFİKASI
CALIBRATION CERTIFICATE

Ölçüm Sonuçları
Measurement Results

Suda Absorblanan Doz Kalibrasyon Katsayısı
Absorbed Dose to Water Calibration Coefficient

Radyasyon / *Radiation*	N_{DW} mGy/nC	U (*) %
Co-60	53,556	1,0

Radyasyon Doz Hızı : 300,972 mGy/dk
Beam Dose Rate

Kalibrasyonda yer değiştirme metodu uygulanmıştır. Kalibrasyon katsayısı N_{DW}, SSDL çalışma standardının atmosferik şartlara göre normalize edilen okuma değeri ("mGy"), müşteri dozimetresiyle alınan okumaların atmosferik şartlara göre normalize edilmiş okuma değerine (mGy veya nC) oranıdır. Referans standardın izlenebilirliği Physikalisch -Technische Bundesanstalt tarafından sağlanmaktadır. Su fantomundaki ölçümler su geçirmez aparat ile alınmıştır. Her iki dozimetre kalibrasyon öncesinde 5 Gy'lik ön ışınlamaya tabi tutulmuştur.

Substitution method is used for the calibration. The calibration coefficient, N_{DW} is the ratio of the conventional true value of the quantity to be measured ("mGy") to the indication of the instrument to be tested (mGy or nC). Traceability of the reference standard was performed by Physikalisch - Technische Bundesanstalt (PTB) Germany. The measurements in the water phantom are taken by ionization chamber within waterproof sleeve. Referans and user dosimeters were pre-irradiated to 5 Gy.

Ölçüm Belirsizliği
Measurement Uncertainty

Kalibrasyon katsayısındaki belirsizlikler, IAEA-TECDOC-1585 numaralı doküman ile "Guide to The Expression of Uncertainty in Measurement" dokümanları esas alınarak hesaplanmıştır.
The uncertainty of calibration coefficient is calculated according to "IAEA-TECDOC-1585" and "Guide to The Expression of Uncertainty in Measurement".

(*) Beyan edilen genişletilmiş ölçüm belirsizliği, standart belirsizliğin, k=2 olarak alınan genişletme katsayısı ile çarpımı sonucunda bulunan değerdir ve yaklaşık %95 oranında güvenilirlik sağlamaktadır.
The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

Görüş/Yorumlar

TRS 398

- Elektrometre :PTW , UNIDOS E
- İyon odası : PTW , TM30013

Suda soğurulan doz kalibrasyon faktörü

N_{DW} = 1,003 mGy/mGy

N_{DW} =53,539 mGy/nC

TABLE 14. CALCULATED VALUES OF k_Q FOR HIGH ENERGY PHOTON BEAMS FOR VARIOUS CYLINDRICAL IONIZATION CHAMBERS AS A FUNCTION OF BEAM QUALITY $TPR_{20,10}$ *(adapted from Andreo [20])*

Ionization chamber type[a]	Beam quality $TPR_{20,10}$														
	0.50	0.53	0.56	0.59	0.62	0.65	0.68	0.70	0.72	0.74	0.76	0.78	0.80	0.82	0.84
Capintec PR-05P mini	1.004	1.003	1.002	1.001	1.000	0.998	0.996	0.994	0.991	0.987	0.983	0.975	0.968	0.960	0.949
Capintec PR-05 mini	1.004	1.003	1.002	1.001	1.000	0.998	0.996	0.994	0.991	0.987	0.983	0.975	0.968	0.960	0.949
Capintec PR-06C/G Farmer	1.001	1.001	1.000	0.998	0.998	0.995	0.992	0.990	0.988	0.984	0.980	0.972	0.965	0.956	0.944
Exradin A2 Spokas	1.001	1.001	1.001	1.000	0.999	0.997	0.996	0.994	0.992	0.989	0.986	0.979	0.971	0.962	0.949
Exradin T2 Spokas	1.002	1.001	0.999	0.996	0.993	0.988	0.984	0.980	0.977	0.973	0.969	0.962	0.954	0.946	0.934
Exradin A1 mini Shonka	1.002	1.002	1.001	1.000	1.000	0.998	0.996	0.994	0.991	0.986	0.982	0.974	0.966	0.957	0.945
Exradin T1 mini Shonka	1.003	1.001	0.999	0.996	0.993	0.988	0.984	0.980	0.975	0.970	0.965	0.957	0.949	0.942	0.930
Exradin A12 Farmer	1.001	1.001	1.000	1.000	0.999	0.997	0.994	0.992	0.990	0.986	0.981	0.974	0.966	0.957	0.944
Far West Tech. IC-18	1.005	1.003	1.000	0.997	0.993	0.988	0.983	0.979	0.976	0.971	0.966	0.959	0.953	0.945	0.934
FZH TK 01	1.002	1.001	1.000	0.998	0.996	0.993	0.990	0.987	0.984	0.980	0.975	0.968	0.960	0.952	0.939
Nuclear Assoc. 30-750	1.001	1.001	1.000	0.999	0.998	0.996	0.994	0.991	0.988	0.984	0.979	0.971	0.963	0.954	0.941
Nuclear Assoc. 30-749	1.001	1.000	1.000	0.999	0.998	0.996	0.994	0.992	0.989	0.984	0.980	0.972	0.964	0.956	0.942
Nuclear Assoc. 30-744	1.001	1.000	1.000	0.999	0.998	0.996	0.994	0.992	0.989	0.984	0.980	0.972	0.964	0.956	0.942
Nuclear Assoc. 30-716	1.001	1.000	1.000	0.999	0.998	0.996	0.994	0.992	0.989	0.984	0.980	0.972	0.964	0.956	0.942
Nuclear Assoc. 30-753 Farmer shortened	1.001	1.000	1.000	0.999	0.998	0.996	0.994	0.992	0.989	0.985	0.980	0.973	0.965	0.956	0.943
Nuclear Assoc. 30-751 Farmer	1.002	1.002	1.000	0.999	0.997	0.994	0.991	0.989	0.985	0.981	0.977	0.969	0.961	0.953	0.940
Nuclear Assoc. 30-752 Farmer	1.004	1.003	1.001	1.000	0.998	0.996	0.993	0.991	0.989	0.985	0.981	0.974	0.967	0.959	0.947

TABLE 14. (cont.)

NE 2515	1.001	1.001	1.000	0.999	0.997	0.994	0.991	0.988	0.984	0.980	0.975	0.967	0.959	0.950	0.937
NE 2515/3	1.005	1.004	1.002	1.000	0.998	0.995	0.993	0.991	0.989	0.986	0.982	0.975	0.969	0.961	0.949
NE 2577	1.005	1.004	1.002	1.000	0.998	0.995	0.993	0.991	0.989	0.986	0.982	0.975	0.969	0.961	0.949
NE 2505 Farmer	1.001	1.001	1.000	0.999	0.997	0.994	0.991	0.988	0.984	0.980	0.975	0.967	0.959	0.950	0.937
NE 2505/A Farmer	1.005	1.003	1.001	0.997	0.995	0.990	0.985	0.982	0.978	0.974	0.969	0.962	0.955	0.947	0.936
NE 2505/3, 3A Farmer	1.005	1.004	1.002	1.000	0.998	0.995	0.993	0.991	0.989	0.986	0.982	0.975	0.969	0.961	0.949
NE 2505/3, 3B Farmer	1.006	1.004	1.001	0.999	0.996	0.991	0.987	0.984	0.980	0.976	0.971	0.964	0.957	0.950	0.938
NE 2571 Farmer	1.005	1.004	1.002	1.000	0.998	0.995	0.993	0.991	0.989	0.986	0.982	0.975	0.969	0.961	0.949
NE 2581 Farmer	1.005	1.003	1.001	0.998	0.995	0.991	0.986	0.983	0.980	0.975	0.970	0.963	0.956	0.949	0.937
NE 2561/2611 Sec. Std	1.006	1.004	1.001	0.999	0.998	0.994	0.992	0.990	0.988	0.985	0.982	0.975	0.969	0.961	0.949
PTW 23323 micro	1.003	1.003	1.000	0.999	0.997	0.993	0.990	0.987	0.984	0.980	0.975	0.967	0.960	0.953	0.941
PTW 23331 rigid	1.004	1.003	1.000	0.999	0.997	0.993	0.990	0.988	0.985	0.982	0.978	0.971	0.964	0.956	0.945
PTW 23332 rigid	1.004	1.003	1.001	0.999	0.997	0.994	0.990	0.988	0.984	0.980	0.976	0.968	0.961	0.954	0.943
PTW 23333	1.004	1.003	1.001	0.999	0.997	0.994	0.990	0.988	0.985	0.981	0.976	0.969	0.963	0.955	0.943
PTW 30001/30010 Farmer	1.004	1.003	1.001	0.999	0.997	0.994	0.990	0.988	0.985	0.981	0.976	0.969	0.962	0.955	0.943
PTW 30002/30011 Farmer	1.006	1.004	1.001	0.999	0.997	0.994	0.992	0.990	0.987	0.984	0.980	0.973	0.967	0.959	0.948
PTW 30004/30012 Farmer	1.006	1.005	1.002	1.000	0.999	0.996	0.994	0.992	0.989	0.986	0.982	0.976	0.969	0.962	0.950
PTW 30006/30013 Farmer	1.002	1.002	1.000	0.999	0.997	0.994	0.990	0.988	0.984	0.980	0.975	0.968	0.960	0.952	0.940
PTW 31002 flexible	1.003	1.002	1.000	0.999	0.997	0.994	0.990	0.988	0.984	0.980	0.975	0.968	0.960	0.952	0.940
PTW 31003 flexible	1.003	1.002	1.000	0.999	0.997	0.994	0.990	0.988	0.984	0.980	0.975	0.968	0.960	0.952	0.940
SNC 100730 Farmer	1.004	1.003	1.001	0.999	0.997	0.993	0.990	0.988	0.985	0.981	0.977	0.970	0.963	0.956	0.944
SNC 100740 Farmer	1.006	1.005	1.002	1.000	0.999	0.996	0.994	0.992	0.990	0.987	0.983	0.977	0.971	0.963	0.951
Victoreen Radocon III 550	1.005	1.004	1.001	0.998	0.996	0.993	0.989	0.986	0.983	0.979	0.975	0.968	0.961	0.954	0.943

TABLE 14. (cont.)

Victoreen Radocon II 555	1.005	1.003	1.000	0.997	0.995	0.990	0.986	0.983	0.979	0.975	0.970	0.963	0.956	0.949	0.938
Victoreen 30-348	1.004	1.003	1.000	0.998	0.996	0.992	0.989	0.986	0.982	0.978	0.973	0.966	0.959	0.951	0.940
Victoreen 30-351	1.004	1.002	1.000	0.998	0.996	0.992	0.989	0.986	0.983	0.979	0.974	0.967	0.960	0.952	0.941
Victoreen 30-349	1.003	1.002	1.000	0.998	0.996	0.992	0.989	0.986	0.983	0.980	0.976	0.969	0.962	0.954	0.942
Victoreen 30-361	1.004	1.003	1.000	0.998	0.996	0.992	0.989	0.986	0.983	0.979	0.974	0.967	0.960	0.953	0.942
Scdx-Wellhöfer IC 05	1.001	1.000	1.000	0.999	0.998	0.996	0.994	0.992	0.989	0.984	0.980	0.972	0.964	0.956	0.942
Scdx-Wellhöfer IC 06	1.001	1.000	1.000	0.999	0.998	0.996	0.994	0.992	0.989	0.984	0.980	0.972	0.964	0.956	0.942
Scdx-Wellhöfer IC 10	1.001	1.000	1.000	0.999	0.998	0.996	0.994	0.992	0.989	0.984	0.980	0.972	0.964	0.956	0.942
Scdx-Wellhöfer IC 15	1.001	1.000	1.000	0.999	0.998	0.996	0.994	0.992	0.989	0.984	0.980	0.972	0.964	0.956	0.942
Scdx-Wellhöfer IC 25	1.001	1.000	1.000	0.999	0.998	0.996	0.994	0.992	0.989	0.984	0.980	0.972	0.964	0.956	0.942
Scdx-Wellhöfer IC 28 Farmer shortened	1.001	1.000	1.000	0.999	0.998	0.996	0.994	0.992	0.989	0.985	0.980	0.973	0.965	0.956	0.943
Scdx-Wellhöfer IC 69 Farmer	1.002	1.002	1.000	0.999	0.997	0.994	0.991	0.989	0.985	0.981	0.977	0.969	0.961	0.953	0.940
Scdx-Wellhöfer IC 70 Farmer	1.004	1.003	1.001	1.000	0.998	0.996	0.993	0.991	0.988	0.985	0.981	0.974	0.967	0.959	0.946

[a] Some of the chambers listed in this table fail to meet some of the minimum requirements described in Section 4.2.1. However, they have been included because of their current clinical use.

TABLE 16. CALCULATED VALUES[a] OF k_Q FOR HIGH ENERGY PHOTON BEAMS FOR VARIOUS CYLINDRICAL IONIZATION CHAMBERS AS A FUNCTION OF THE BEAM QUALITY INDEX $TPR_{20,10}$ *(see Eq. (34))* (cont.)

Ionization chamber type	Beam quality index, $TPR_{20,10}$											
	0.56	0.59	0.62	0.65	0.68	0.70	0.72	0.74	0.76	0.78	0.80	0.82
PTW 30010 Farmer	1.0005	0.9989	0.9967	0.9938	0.9901	0.9869	0.9832	0.9787	0.9734	0.9671	0.9595	0.9506
PTW 30011 Farmer	1.0005	0.9989	0.9969	0.9942	0.9906	0.9875	0.9838	0.9793	0.9739	0.9674	0.9595	0.9501
PTW 30012 Farmer	1.0004	0.9990	0.9970	0.9944	0.9910	0.9881	0.9846	0.9804	0.9754	0.9694	0.9622	0.9536
PTW 30013 Farmer	1.0007	0.9984	0.9956	0.9920	0.9876	0.9840	0.9800	0.9753	0.9699	0.9636	0.9565	0.9484
PTW 31010 Semiflex	1.0008	0.9982	0.9952	0.9914	0.9869	0.9835	0.9795	0.9750	0.9700	0.9643	0.9579	0.9507
PTW 31013 Semiflex	1.0007	0.9985	0.9958	0.9924	0.9882	0.9848	0.9810	0.9765	0.9714	0.9655	0.9588	0.9511
PTW 31016 PinPoint 3D[b]	1.0006	0.9987	0.9962	0.9930	0.9888	0.9853	0.9812	0.9762	0.9703	0.9632	0.9549	0.9451

TABLE 16. CALCULATED VALUES[a] OF k_Q FOR HIGH ENERGY PHOTON BEAMS FOR VARIOUS CYLINDRICAL IONIZATION CHAMBERS AS A FUNCTION OF THE BEAM QUALITY INDEX $TPR_{20,10}$ *(see Eq. (34))* (cont.)

Ionization chamber type	Beam quality index, $TPR_{20,10}$											
	0.56	0.59	0.62	0.65	0.68	0.70	0.72	0.74	0.76	0.78	0.80	0.82
PTW 31021 Semiflex 3D[b]	1.0007	0.9984	0.9957	0.9925	0.9886	0.9856	0.9823	0.9786	0.9744	0.9697	0.9645	0.9587
PTW 31022 PinPoint 3D[b]	1.0005	0.9989	0.9968	0.9940	0.9905	0.9875	0.9840	0.9798	0.9749	0.9690	0.9621	0.9540
Sun Nuclear SNC125c	1.0005	0.9991	0.9971	0.9944	0.9908	0.9878	0.9840	0.9794	0.9739	0.9671	0.9590	0.9492
Sun Nuclear SNC600c Farmer	1.0004	0.9993	0.9978	0.9957	0.9926	0.9899	0.9866	0.9823	0.9770	0.9703	0.9620	0.9517

[a] Values are given to four decimal places to permit smooth interpolation of the data. This does not imply uncertainties of this order.

[b] Although the sensitive volume of the chamber is smaller than the recommendations given in Section 4.2.1, the chamber is included here because it is advantageous for dose measurements in FFF beams.

TABLE 4. CHARACTERISTICS OF CYLINDRICAL CHAMBER TYPES *(as stated by manufacturers)*

Ionization chamber type	Cavity volume (cm^3)	Cavity length (mm)	Cavity radius (mm)	Wall material	Wall thickness (g/cm^2)	Central electrode material	Waterproof
NE 2571	0.69	24.1	3.2	Graphite	0.065	Aluminium	No
PTW 30010	0.6	23.0	3.1	PMMA/graphite	0.057	Aluminium	No
PTW 30012	0.6	23.0	3.1	Graphite	0.079	Aluminium	No
PTW 30013	0.6	23.0	3.1	PMMA/graphite	0.057	Aluminium	Yes
PTW 31010[a]	0.13	6.5	2.8	PMMA/graphite	0.078	Aluminium	Yes
PTW 31013	0.3	16.3	2.8	PMMA/graphite	0.078	Aluminium	Yes
PTW31021	0.07	4.8	2.4	PMMA/graphite	0.084	Aluminium	Yes
IBA CC13	0.13	5.8	3.0	C552	0.070	C552	Yes
IBA FC65-G	0.65	23.0	3.1	Graphite	0.073	Aluminium	Yes
IBA FC65-P	0.65	23.0	3.1	POM	0.057	Aluminium	Yes
Exradin A12	0.64	n.a.[b]	3.1	C-552	0.088	C-552	Yes
Exradin A19	0.62	n.a.[b]	3.1	C-552	0.088	C-552	Yes

[a] Although PTW 31010 does not meet the reference class specification, as demonstrated in Ref. [98], it is included here as an option for flattening filter free beams, where a shorter thimble is potentially advantageous. Use of this chamber type requires additional characterization and may result in a larger overall uncertainty in the determination of absorbed dose to water.

[b] n.a.: not applicable. Manufacturer data state 21.6 mm for the electrode length, and 26.5 mm (A12) and 26.2 mm (A19) for a so called 'spot size', defined as the smallest circle that inscribes the collecting volume and shell.

TABLE 17. ESTIMATED RELATIVE STANDARD UNCERTAINTY[a] OF $D_{w,Q}$ AT THE REFERENCE DEPTH IN WATER AND FOR A HIGH ENERGY PHOTON BEAM, BASED ON A CHAMBER CALIBRATION IN ^{60}Co GAMMA RADIATION

Physical quantity or procedure	Relative standard uncertainty (%)
Step 1: standards laboratory[b]	
$N_{D,w}$ calibration of secondary standard at PSDL	0.5
Long term stability of secondary standard	0.1
$N_{D,w}$ calibration of the user dosimeter at the standards laboratory	0.4
Combined uncertainty of step 1	0.6
Step 2: user's high energy photon beam	
Long term stability of user dosimeter	0.2
Establishment of reference conditions	0.3
Dosimeter reading M_Q relative to beam monitor	0.3[c]
Correction for influence quantities k_i	0.3
Beam quality factor, k_Q [100]	0.6[d]
Combined uncertainty of step 2	0.8
Combined standard uncertainty of $D_{w,Q}$ (steps 1 and 2)	1.0

TABLE 13. ESTIMATED RELATIVE STANDARD UNCERTAINTY[a] OF D_w AT THE REFERENCE DEPTH IN WATER FOR A ^{60}Co BEAM

Physical quantity or procedure	Relative standard uncertainty (%)
Step 1: standards laboratory[b]	
$N_{D,w}$ calibration of secondary standard at PSDL	0.5
Long term stability of secondary standard	0.1
$N_{D,w}$ calibration of the user dosimeter at the standards laboratory	0.4
Combined uncertainty of step 1	0.6
Step 2: user ^{60}Co beam	
Long term stability of user dosimeter	0.2
Establishment of reference conditions	0.3
Dosimeter reading M_Q relative to timer or beam monitor	0.1
Correction for influence quantities k_i	0.3
Combined uncertainty of step 2	0.5
Combined standard uncertainty of D_w (steps 1 and 2)	0.8

Foton Dozimetrisi TRS 398

Z_{ref} derinliğinde Q demet kalitesinde bir foton demeti için iyon odası yokluğunda suda soğurulan doz;

$$D_{w,Q} = M_Q N_{D,w,Q_0} k_{Q,Q_0}$$

M_Q : Sıcaklık ve basınç; elektrometre kalibrasyonu; polarite etkisi ve iyon tekrar birleşme etkileri için düzeltilmiş dozimetre okuması

N_{D,w,Q_0} :Referans kalite Q_0 da dozimetre için suda soğurulan doz kalibrasyon faktörüdür.

k_{Q,Q_0} :İyon odasına özel faktördür.Referans demet kalitesi Q_0 ve gerçek demet kalitesi Q arasındaki farkları düzeltir.

Tablo 21.Bazı plastikler için c_{pl} derinlik dönüştürme faktörü, h_{pl} akı dönüştürme faktörü,nominal yoğunluklar

Plastik fantom	c_{pl}	h_{pl}	ρ_{pl} (g / cm^3)
Katı su (WT1)	0.949	1.011	1.020
Katı su (RM1-457)	0.949	1.008	1.030
Plastik su	0.982	0.998	1.013
Sanal su	0.946	-	1.030
PMMA	0.941	1.009	1.190
Şeffaf polistren	0.922	1.026	1.060
Beyaz polistren	0.922	1.026	1.060
A-150	0.922	1.026	1.060

Düzeltme faktörleri

$$k_{Tp}=\frac{(273.2+T)}{(273.2+T_0)}\,\frac{P_0}{P}$$

Sıcaklık-basınç

Düzeltme faktörleri

- Polarite düzeltmesi

$$Kpol=\frac{|M+| + |M-|}{2M}$$

Tekrar birleşme düzeltmesi (İki voltaj yöntemi)

$$k_s=a_0 + a_1(M_1/M_2)+(M_1/M_2)^2$$

$$k_{vol} = 1 + \left(0.0062\,TPR_{20,10} - 0{,}0036\right) \times \left(\frac{100}{SDD}\right)^2 \times L^2$$

L: Kavite uzunluğu

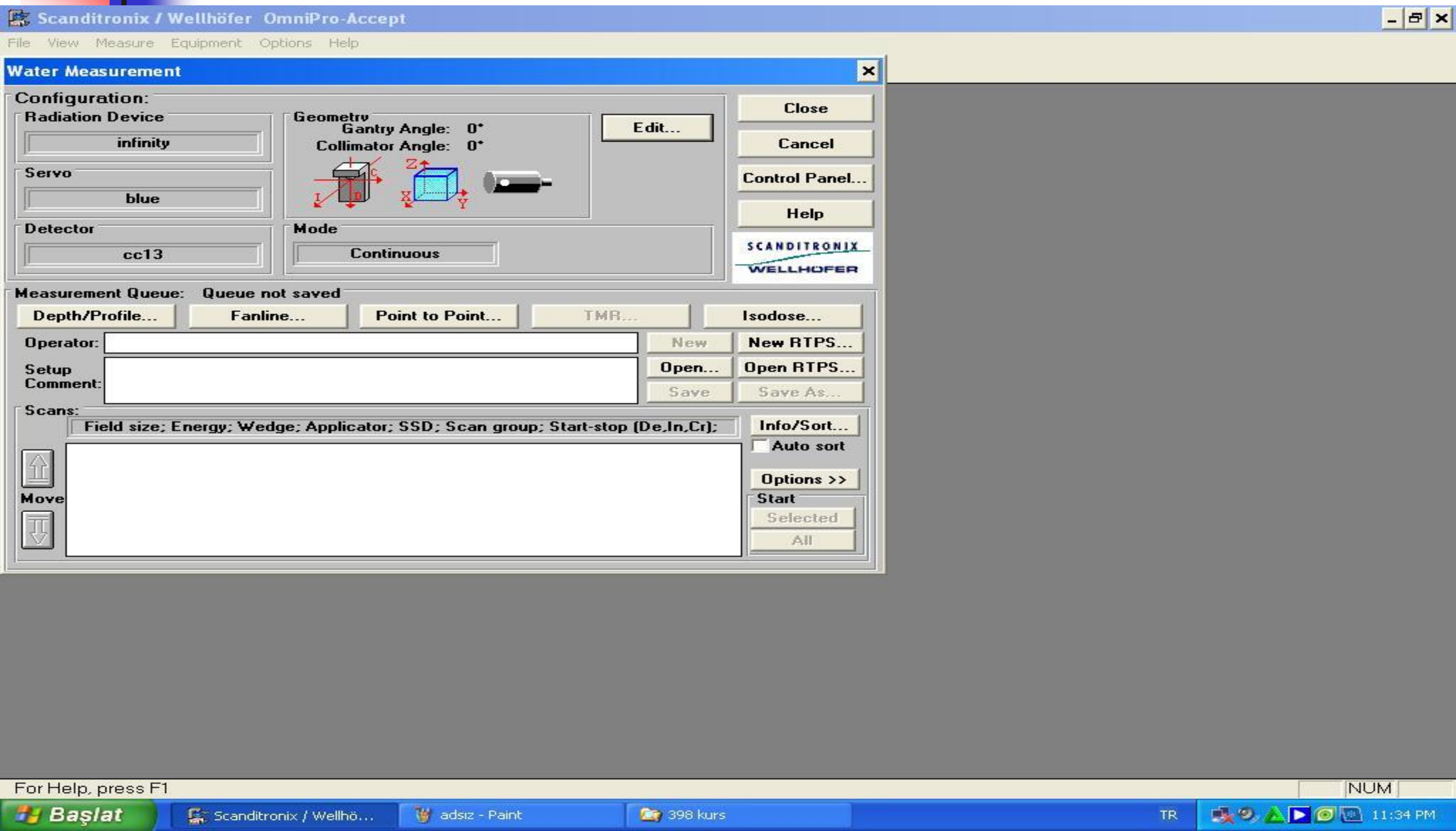
SDD: Kaynak dedektör mesafesi

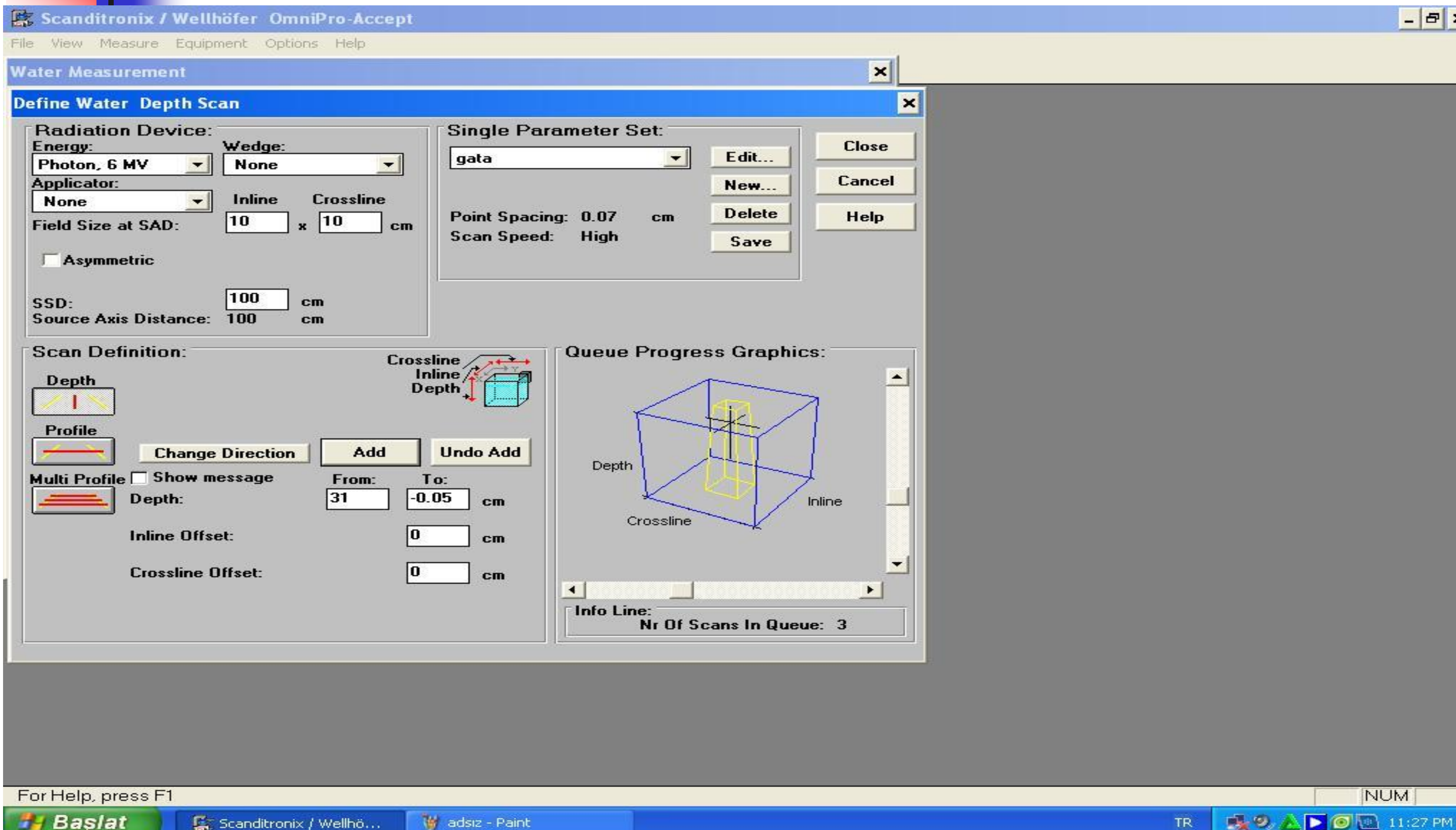
Tablo 11'de hacim ortalama düzeltme faktörleri farklı kavite uzunlukları için SDD = 110 cm için hesaplanmışlardır.

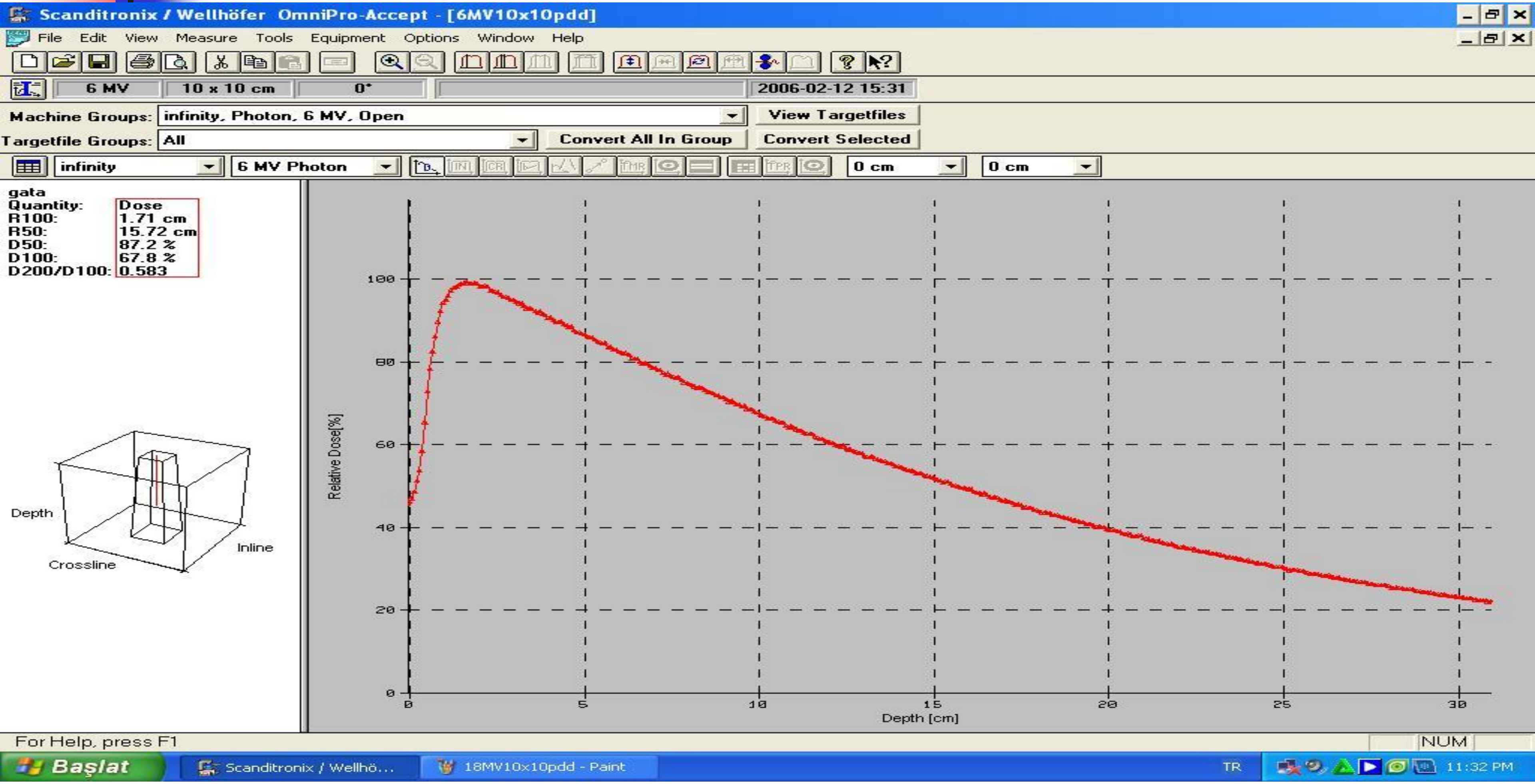
Suda Soğurulan Doz

- $D_{w,Q(ref)} = M_Q \, N_{D,w,Q0} \, k_{Q,Q0}$ Gy/MU

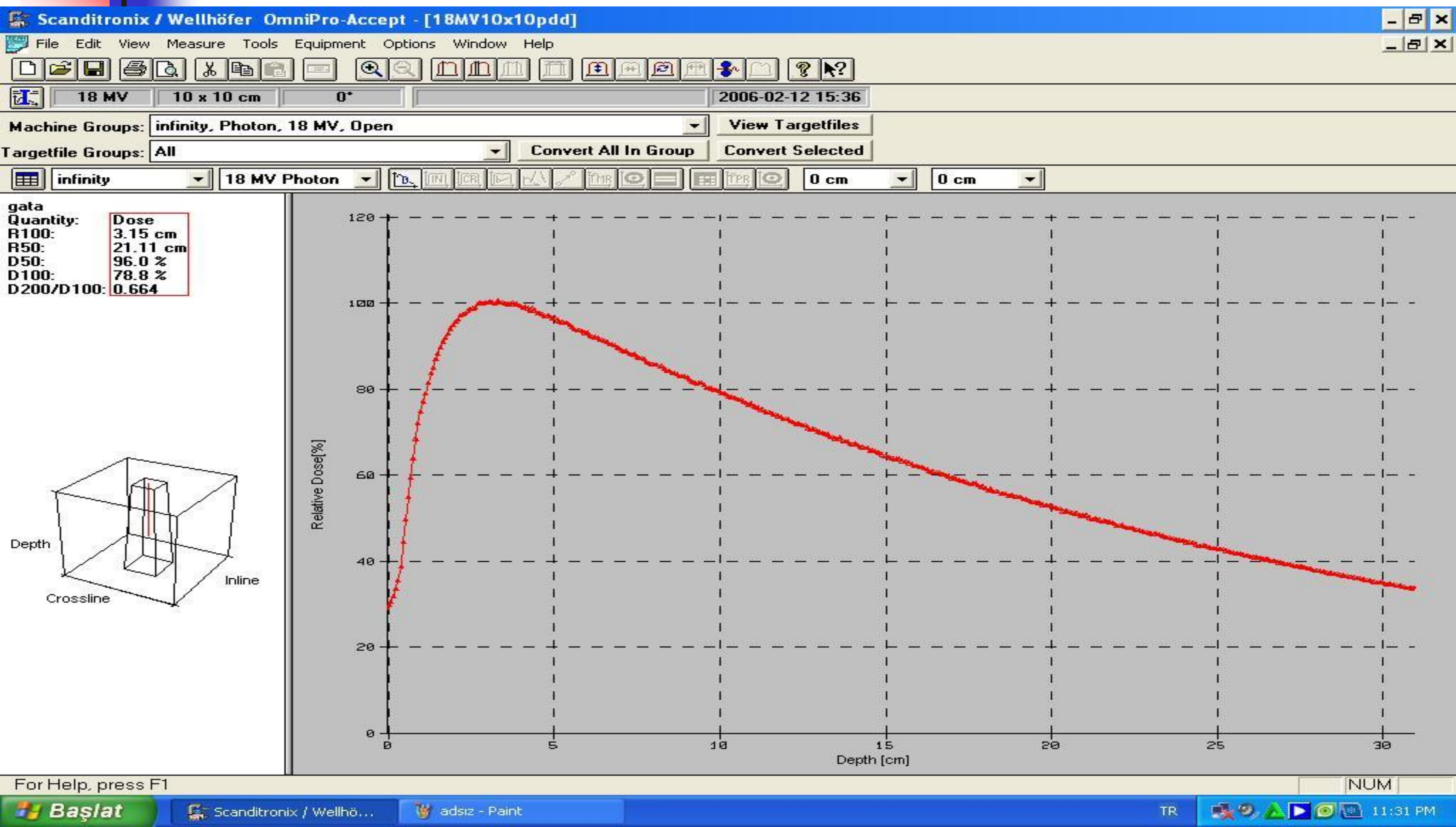
- $D_{w,Q}\,(Z_{max}) = 100\, D_{w,Q}(Z_{ref}) \,/\, PDD(z_{ref})$


Scanditronix / Wellhöfer OmniPro-Accept
File View Measure Equipment Options Help
Water Measurement
Configuration:
Radiation Device
infinity
Servo
blue
Detector
cc13
Geometry
Gantry Angle: 0°
Collimator Angle: 0°
Edit...
Mode
Continuous
Close
Cancel
Control Panel...
Help
SCANDITRONIX
WELLHOFER
Measurement Queue: Queue not saved
Depth/Profile...
Fanline...
Point to Point...
TMR...
Isodose...
Operator:
New
New RTPS...
Setup Comment:
Open...
Open RTPS...
Save
Save As...
Scans:
Field size; Energy; Wedge; Applicator; SSD; Scan group; Start-stop (De,In,Cr);
Info/Sort...
Auto sort
Move
Options >>
Start
Selected
All
For Help, press F1
NUM
Başlat
Scanditronix / Wellhö...
adsız - Paint
398 kurs
TR
11:34 PM

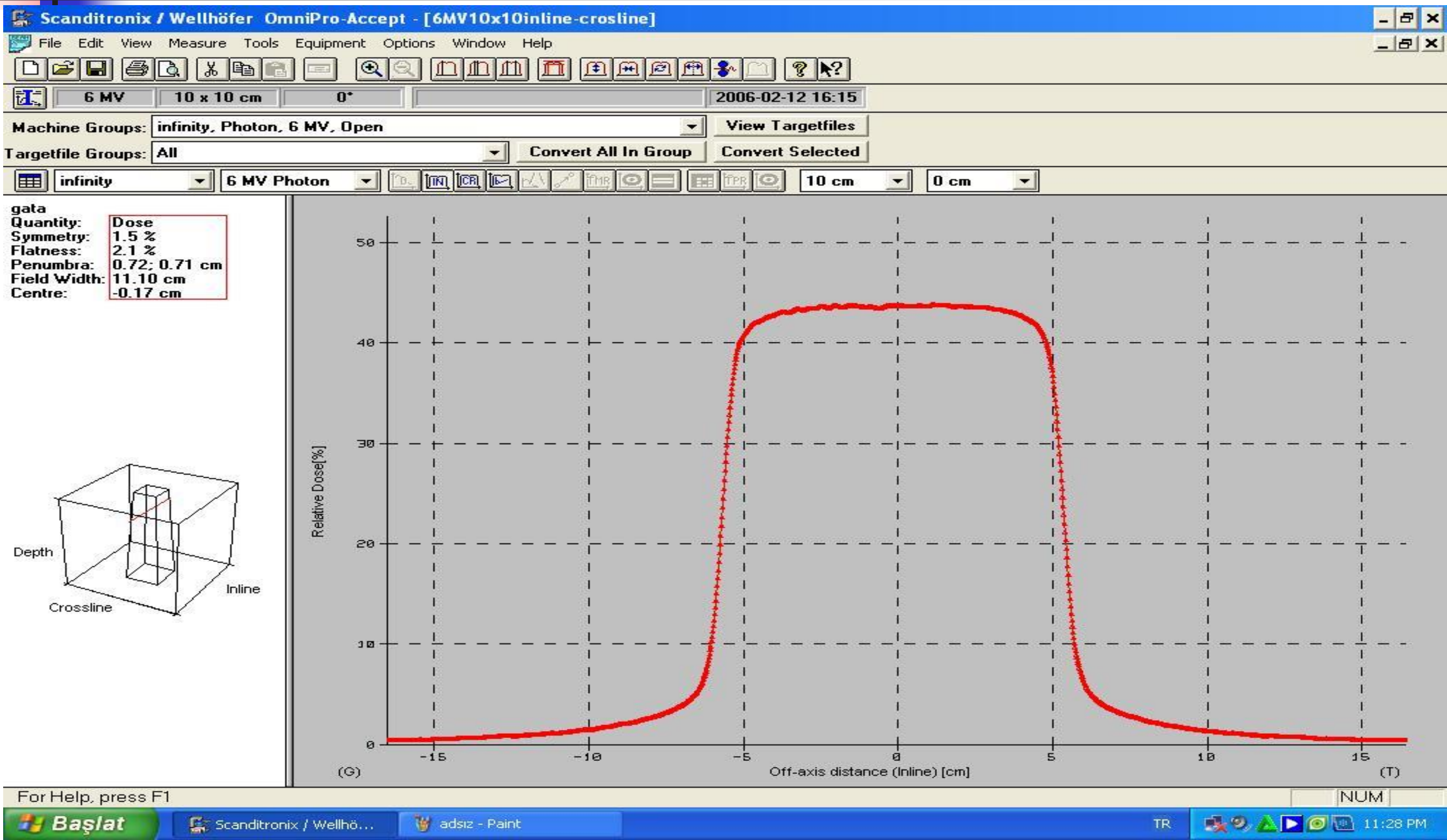

Scanditronix / Wellhöfer OmniPro-Accept
File View Measure Equipment Options Help
Water Measurement
Define Water Depth Scan
Radiation Device:
Energy:
Photon, 6 MV
Wedge:
None
Applicator:
None
Inline
Crossline
Field Size at SAD:
10
x
10
cm
Asymmetric
SSD:
100
cm
Source Axis Distance:
100
cm
Single Parameter Set:
gata
Edit...
New...
Delete
Save
Point Spacing: 0.07 cm
Scan Speed: High
Close
Cancel
Help
Scan Definition:
Crossline
Inline
Depth
Depth
Profile
Multi Profile
Change Direction
Add
Undo Add
Show message
From:
To:
Depth:
31
-0.05
cm
Inline Offset:
0
cm
Crossline Offset:
0
cm
Queue Progress Graphics:
Depth
Inline
Crossline
Info Line:
Nr Of Scans In Queue: 3
For Help, press F1
NUM
Başlat
Scanditronix / Wellhö...
adsız - Paint
TR
11:27 PM



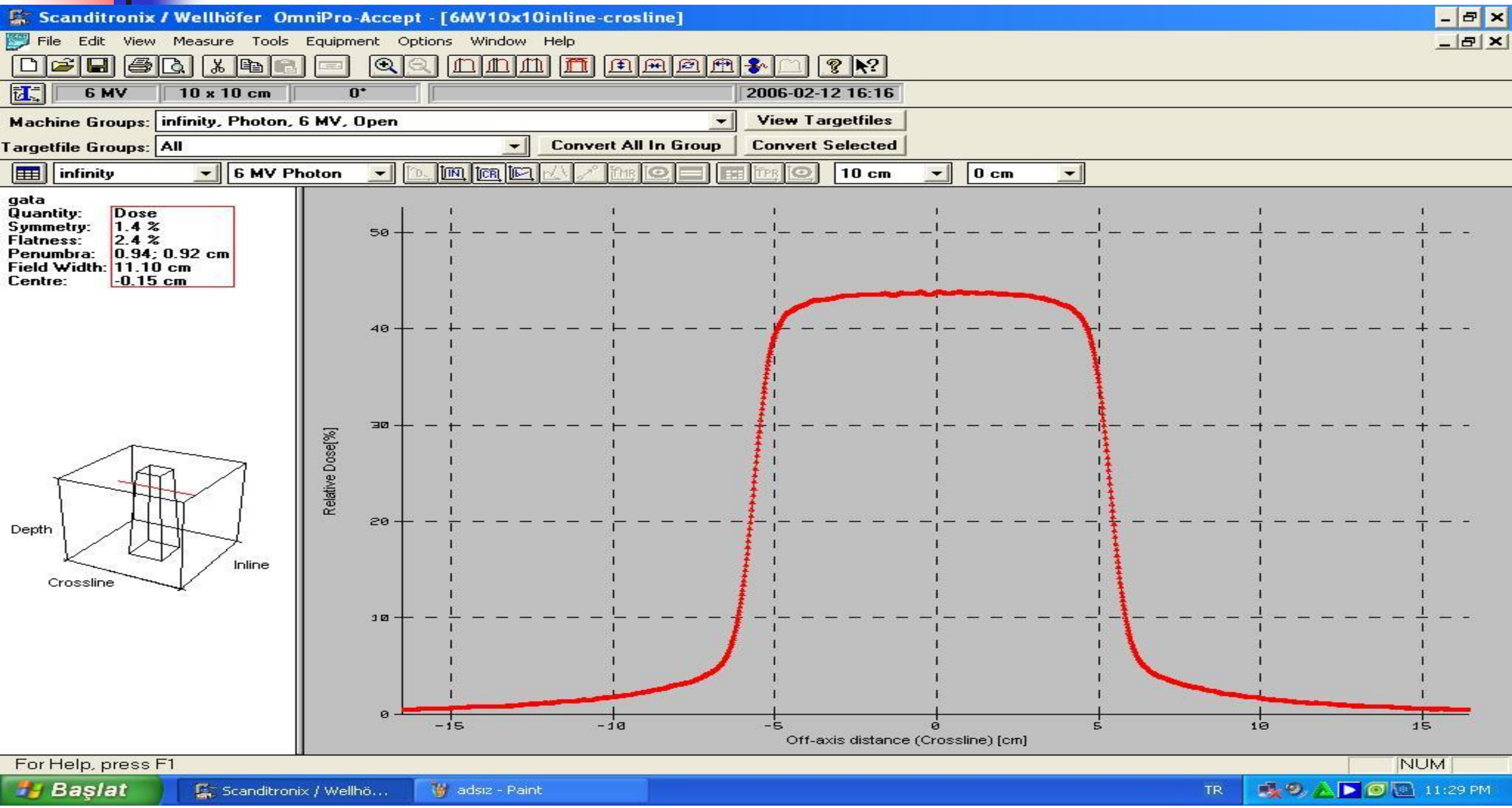
Scanditronix / Wellhöfer OmniPro-Accept - [6MV10x10pdd]
File Edit View Measure Tools Equipment Options Window Help
6 MV
10 x 10 cm
0°
2006-02-12 15:31
Machine Groups: infinity, Photon, 6 MV, Open
View Targetfiles
Targetfile Groups: All
Convert All In Group
Convert Selected
infinity
6 MV Photon
0 cm
0 cm
gata
Quantity: Dose
R100: 1.71 cm
R50: 15.72 cm
D50: 87.2 %
D100: 67.8 %
D200/D100: 0.583
Depth
Inline
Crossline
Relative Dose[%]
Depth [cm]
For Help, press F1
NUM
Başlat
Scanditronix / Wellhö...
18MV10x10pdd - Paint
TR
11:32 PM



Scanditronix / Wellhöfer OmniPro-Accept - [18MV10x10pdd]
File Edit View Measure Tools Equipment Options Window Help
18 MV
10 x 10 cm
0°
2006-02-12 15:36
Machine Groups: infinity, Photon, 18 MV, Open
View Targetfiles
Targetfile Groups: All
Convert All In Group
Convert Selected
infinity
18 MV Photon
0 cm
0 cm
gata
Quantity: Dose
R100: 3.15 cm
R50: 21.11 cm
D50: 96.0 %
D100: 78.8 %
D200/D100: 0.664
Depth
Inline
Crossline
Relative Dose[%]
Depth [cm]
For Help, press F1
NUM
Başlat
Scanditronix / Wellhö...
adsız - Paint
TR
11:31 PM



Scanditronix / Wellhöfer OmniPro-Accept - [6MV10x10inline-crosline]
File Edit View Measure Tools Equipment Options Window Help
6 MV
10 x 10 cm
0°
2006-02-12 16:15
Machine Groups: infinity, Photon, 6 MV, Open
View Targetfiles
Targetfile Groups: All
Convert All In Group
Convert Selected
infinity
6 MV Photon
10 cm
0 cm
gata
Quantity: Dose
Symmetry: 1.5 %
Flatness: 2.1 %
Penumbra: 0.72; 0.71 cm
Field Width: 11.10 cm
Centre: -0.17 cm
Depth
Crossline
Inline
Relative Dose[%]
50
40
30
20
10
0
-15
-10
-5
0
5
10
15
(G)
Off-axis distance (Inline) [cm]
(T)
For Help, press F1
NUM
Başlat
Scanditronix / Wellhö...
adsız - Paint
TR
11:28 PM


Scanditronix / Wellhöfer OmniPro-Accept - [6MV10x10inline-crosline]
File Edit View Measure Tools Equipment Options Window Help
6 MV
10 x 10 cm
0°
2006-02-12 16:16
Machine Groups: infinity, Photon, 6 MV, Open
View Targetfiles
Targetfile Groups: All
Convert All In Group
Convert Selected
infinity
6 MV Photon
10 cm
0 cm
gata
Quantity: Dose
Symmetry: 1.4 %
Flatness: 2.4 %
Penumbra: 0.94; 0.92 cm
Field Width: 11.10 cm
Centre: -0.15 cm
Depth
Inline
Crossline
Relative Dose[%]
50
40
30
20
10
0
-15
-10
-5
0
5
10
15
Off-axis distance (Crossline) [cm]
For Help, press F1
NUM
Başlat
Scanditronix / Wellhö...
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11:29 PM

PROFİL DÜZGÜNLÜĞÜNÜN (Flatness) VE SİMETRİSİNİN KONTROLÜ:

(Tolerans ± %3)

Kullanılan 30x30 cm^2'lik alan ve 10 x 10 cm^{2}' lik alan için ayrı ayrı 10cm derinlikte GT(inplane) ve AB(crossplane) yönlerinde elde edilecek profil düzgünlük (Flatness) ve simetri açısından değerlendirilir.

PROFİL DÜZGÜNLÜĞÜ (Flatness)

$$F = \frac{M-m}{M+m} \times 100\ \%$$

AAPM Task Grup 40 'a göre;

Alan genişliğinin (% 50 deki genişlik)

M, % 80'nindeki maksimum doz

m, % 80'nindeki minimum dozdur.


Teşekkür Ederim