Veterans Administration

Medical Center
2002 Holcombe Boulevard
Houston, TX 77211

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Francis A. St. Mary
Materials Licensing Branch
Division of Fuel Cycle and
Material Safety
United States Nuclear Regulatory
Commission
Washington, D. C. 20555

Dear Sir:

This is in reference to your letter dated March 28, 1984, requesting additional information to complete the evaluation of our report dated February 7, 1984, Control No. 17007.

1. a. The Ludlum Model 12 survey instrument was calibrated by Philip H. Cooper, Ph.D.

   b. The standard used for this calibration is a Model 64-764, S/N157 Cesium 137, 100 millicuris, sealed source as of March 9, 1973; was purchased from Victoreen/Nuclear Associates; is NBX traceable; and emits, with the source in the irradiation position, 45 mR/hr at 30 inches as of March 9, 1973. The survey instrument is calibrated every six months in the following manner. After calculating for decay, distances are chosen to deliver 14 exposure rates between 0.5 and 400 mR to include two exposure values in the midrange of each of three scale factors on the survey instrument from a full scale reading of 2 mR/hr to 600 mR/hr.

   c. The primary dosimetry system used to perform the calibration of the teletherapy unit was the Capintec Model 192A Electrometer, Serial #57F174, and Capintec chamber Model PR-06C, Serial #C110.6290. Also used in the calibration was a Keithley electromotor Model 615, Serial #77269, and a Nuclear Enterprises, Ltd., Farmer chamber Model 2502/2, Serial #152.

   d. The dosimetry system was calibrated by the Regional Calibration Laboratory at the M. D. Anderson Hospital and Tumor Institute in Houston, Texas. Enclosed is a copy of the calibration report for the instrument which shows it to be in compliance with 10 CFR 35.23.

In Reply Refer To: 580/190

United States Nuclear Regulatory Commission
Washington, D. C.

2. The output stated as of August 30, 1983, was from the manufacturer's test cell report. This was not used to treat patients. Instead, immediately after source installation and before resumption of patient treatments, a full calibration of the teletherapy unit was performed in compliance with 10 CFR 35.21. Enclosed is a copy of the results as recorded in the teletherapy unit logbook.

3. a. The teletherapy source "on-off" indicators are "source-on" and "source-off" lights at the source housing, at the teletherapy machine control panel, and above the entrance to the treatment room door. The mechanical indicator is a rod which extends from the source housing when the source is in the "on" position and retracts when the source returns to the "off" position. Both mechanical and electrical indicators at the source housing are observed to function via a television monitoring system. All indicators were observed to correctly indicate the source to be in the "on" position or the "off" position. The position of the source was verified by measurement of the exposure rate with the dosimetry system.

b. Use of the dosimetry system to determine exposure rate shows the source to return to the "off" position at the end of the present time. Turning the "source-on" control does not cause the source to return to the "on" position until the timer has been reset.

JOHN V. SHEEHAN
Director

Enclosures:

1. Report of calibration
2. Calculation of posted outputs

Y0349

The University of Texas System Cancer Center

M. D. Anderson Hospital and Tumor Institute
Texas Medical Center • 6723 Bertner Avenue • Houston, Texas 77030

Department of Physics

Instrument submitted by:

David Gager - Radiotherapy
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Report # 035

REGIONAL CALIBRATION LABORATORY

Report of Calibration

Date instrument received for calibration: December 28, 1981

Date instrument calibration completed: January 29, 1982

Date calibration report completed: August 12, 1982

Description of instrument:

Capintec Exposure/Exposure Rate Meter Model 192A, Serial # 57F174
Capintec Chamber Model PR-06C (0.6 ml, AE plastic), Serial # CII0.6290
Polystyrene Buildup Cap, # CII0.6290

NOTE: Proper function and reliability of the radiation measuring devices described in this document are highly dependent upon handling and use. Therefore, the duration of responsibility of The University of Texas System Cancer Center, M. D. Anderson Hospital and Tumor Institute, and its employees for the calibration results extends only to the time the instruments leave the M. D. Anderson Hospital premises. It is recommended that the instrument user establish an appropriate technique of monitoring the constancy of the instrument response before and after its submission to the Regional Calibration Laboratory and on a regular basis thereafter. In addition, it is the express responsibility of the instrument user to assure himself (by personal communication, if necessary) that his interpretation of the information in this document is consistent with the interpretation intended by the Regional Calibration Laboratory.

NOTE: The Capintec Model 192A, # 57F1. supplied only 250 volts polarizing voltage instead of the nominal 305 volts, due to a weak battery. The Regional Calibration Laboratory used its own battery for the chamber calibration.

CALIBRATION FACTORS:

R/rdg: Roentgen/reading calibration factors apply to the chamber-electrometer-readout system as a unit, with scales, switch settings and output mode specified. To obtain the exposure in roentgens at the geometrical center of the ion chamber volume*, in the absence of the chamber, the calibration factor is applied directly to the instrument reading corrected for temperature and pressure.

R/C: Roentgen/coulomb calibration factors apply to the ion chamber alone. To obtain the exposure in roentgens at the geometrical center of the ion chamber volume*, in the absence of the chamber, an appropriately calibrated (coulomb/reading) electrometer must be used.

TEMPERATURE-PRESSURE CORRECTION FACTOR:

For chambers open to the atmosphere, the instrument readings were normalized to 760 millimeters of mercury and 22 degrees Celsius. Use of the chamber at other pressures and temperatures requires correction by the following multiplicative factor:

$$\frac{T + 273.15}{295.15} \times \frac{760}{P}$$

where T is the temperature in degrees Celsius, and P is the chamber pressure in millimeters of mercury.

No corrections were made for air humidity.

CALIBRATION CONDITIONS:

Calibration field size is given by the dimension across the field from one 50-percent intensity line to the other (in air) measured at the calibration distance. Stem effect was not investigated; the calibration factor applies only to the field size stated.

During calibration the chamber was centered in the beam with the stem perpendicular to the beam direction, except for end-window chambers which are calibrated with the stem parallel to the beam direction.

The sign of the polarizing voltage indicates the thimble potential relative to the collecting electrode, although the thimble may actually be grounded.

The exposure rate at the calibration position was measured with a transfer-quality ionization chamber which was calibrated at the National Bureau of Standards.

The overall accuracy of the calibration factors assigned by the Regional Calibration Laboratory is believed to be within 2.5%, which includes the uncertainty inherent in the determination of the roentgen.

BEAM QUALITY:

Medium energy x-ray beam quality is described in terms of the first half-value thickness in millimeters of aluminum or copper, the ratio of the first to the second half-value thickness, and the peak kilovoltage.

The half-value thicknesses were determined with a 2 cm diameter aperture and high purity aluminum or copper absorbers. The aperture and ion chamber were positioned at 50 cm and 100 cm, respectively, from the target.

*The center of end-window chambers is normally designated by a circular groove.

REGIONAL CALIBRATION LABORATORY
M. D. ANDERSON HOSPITAL AND TUMOR INSTITUTE

Report of Calibration

INSTRUMENT:

Capintec Chamber Model PR-06C (0.6 ml, AE plastic), Serial # CII0.6290
Polystyrene Buildup Cap, # CII0.6290 (Cobalt-60 radiation only)

SCALES, SWITCH POSITIONS, AND CONDITIONS:

Chamber Only

Field Size: 10 x 10 cm^2

Preirrad. Leakage: -1×10^{-14} A

Orientation: Air hole toward beam

Nominal Full Scale: N/A

Polarizing Voltage: -300 V
(on thimble)

BEAM QUALITY HVT(mm)	1st/2nd	kVp	EXPOSURE RATE (R/min)	CALIBRATION* FACTOR (R/C)	% FULL SCALE or (Total Exposure)
2.58 Al	0.58	100	55	$4.70_9 \times 10^9$	N/A
1.86 Cu	0.64	250	61	$4.86_7 \times 10^9$	N/A
2.98 Cu	0.84	250	33	$4.89_7 \times 10^9$	N/A
Cobalt-60			37	$4.98_5 \times 10^9$	N/A

*At 22°C, 760 mmHg: The chamber was determined to be open to atmospheric communication.

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Robert J. Shalek

REGIONAL CALIBRATION LABORATORY
M. D. ANDERSON HOSPITAL AND TUMOR INSTITUTE

Report of Calibration

INSTRUMENT:

Capintec Exposure/Exposure Rate Meter Model 192A, Serial # 57F174

SCALES, SWITCH POSITIONS, AND CONDITIONS:

Electrometer Switch: Position

PROBE SELECTOR: ELECTROMETER
COMPENSATION FACTOR: 1.00
METER RANGE: NORMAL } (199.9 full scale)
EXPOSURE LEVEL: HIGH }
MODE: TOTAL

NOTE: ZERO ADJUST and BACKGROUND were adjusted in accordance with the Capintec 192 Operation Manual. However, any zero offset or zero drift should be taken into account, if significant to the reading being taken.

CHARGE CALIBRATION FACTOR:

$0.85_9 \times 10^{-9}$ C/unit of reading

NOTE: The charge sensitivity (rdg/C) was constant to within ± 0.1% over the range of readings from +51.2 to +199.7.

EXAMPLE: Assume that the chamber described on page 3 is being used with the electrometer and switch settings described above , that the temperature-pressure correction is 1.000, and that the reading is 100.0 (i.e. 50% full scale); then the exposure for Cobalt-60 radiation would be 100.0 x 0.859 x 10(-9) x 4.985 x 10(+9) = 428 R. Nominal full scale is 855 R.

DATA BOOK 15 ; PAGE 158

Robert J. Shalek

Calculation of Posted Outputs 80cm SSD

28 OCTOBER

-0349

(1) in air (pgs 29, 35) extrapolated to water: $175.87 \frac{rad}{min}$

$175.15 \frac{rad}{min}$

(2) calibration @ 80 cm SSD in water (pg 37) $176.42 \frac{rad}{min}$

average data in (1) & (2) yields

ave $\dot{D} = 175.81 \frac{rad}{min}$ in water for $10 \times 10 cm^2$ field @ 80 cm SSD, d_{max} depth, on 28 Oct 1983

decay 19 days to 15 November 1983:

$$\dot{D} = \left(175.81 \frac{rad}{min}\right) e^{-\left(\frac{\ln 2}{5.261 y}\right)\left(\frac{1y}{365d}\right) 19d} = 174.61 \frac{rad}{min}$$

(see pg 35 for calc of in air std)

−4.405 % for tray reduction in transmission (pg 45):

$$\dot{D} = \left(174.61 \frac{rad}{min}\right)(0.95595) = 166.92 \frac{rad}{min}$$

Posted Outputs* (Posted 1 Nov 1983)

80 cm SSD

$10 \times 10 cm^2$ field (45 cm STD); outputs are dose rates @ d_{max} in tissue (see *, pg 44) for 15 Nov 1983

no tray: $174.5 \frac{rad}{min}$ $\left(174.0 \frac{rad}{min}\right)$

tray: $167.0 \frac{rad}{min}$ $\left(166.0 \frac{rad}{min}\right)$

*- Actual posted outputs noted in green; differences due to different extrapolation method (air to water calculations) -- previously Ca [illegible] data were applied rather than Aug, Lanter & [illegible] data. Following posted outputs will be based on data & [illegible] presented on this page.

28 OCTOBER 1983 In air Calibration

10 x 10 cm² field @ 80 cm SSD, 45 cm STD (always);
probe centered in field @ 80.5 cm from source.
BKeithley / Farmer chm #152 CCF = 538.6
T = 25.8°C CP = 770.8 mm Hg TPCF = 0.99868
(T)
exposure setting: 1.00 min
readings: 0.3305, 0.331, 0.332, 0.332, 0.332, 0.332
average: $0.33158\overline{3}$ (R_1)

output in air = ave × TPCF × CCF × A_{eq} × f_{muscle} ÷ exp set
$= 0.33158\overline{3} \times 0.99868 \times 538.6 \times 0.985 \times 0.957 \div 1.00\,\text{min}$
$= 168.13\ \frac{\text{rad}}{\text{min}}$ in air for 10 x 10 cm² field @ 80 cm SSD (dose rate delivered to small mass of muscle at this position)

In air measurement extrapolated to dose rate in water phantom, with probe immersed @ depth of 5 mm, 80 cm SSD to water surface, all other conditions unchanged:

output in water (projected) = BSF* × ave × TPCF × CCF × A_{eq} × f_{water}+ ÷ exp set

$$= \frac{1.0395 \times 0.331583 \times 0.99868 \times 538.6 \times 0.985 \times 0.966}{1.00\,\text{min}}$$

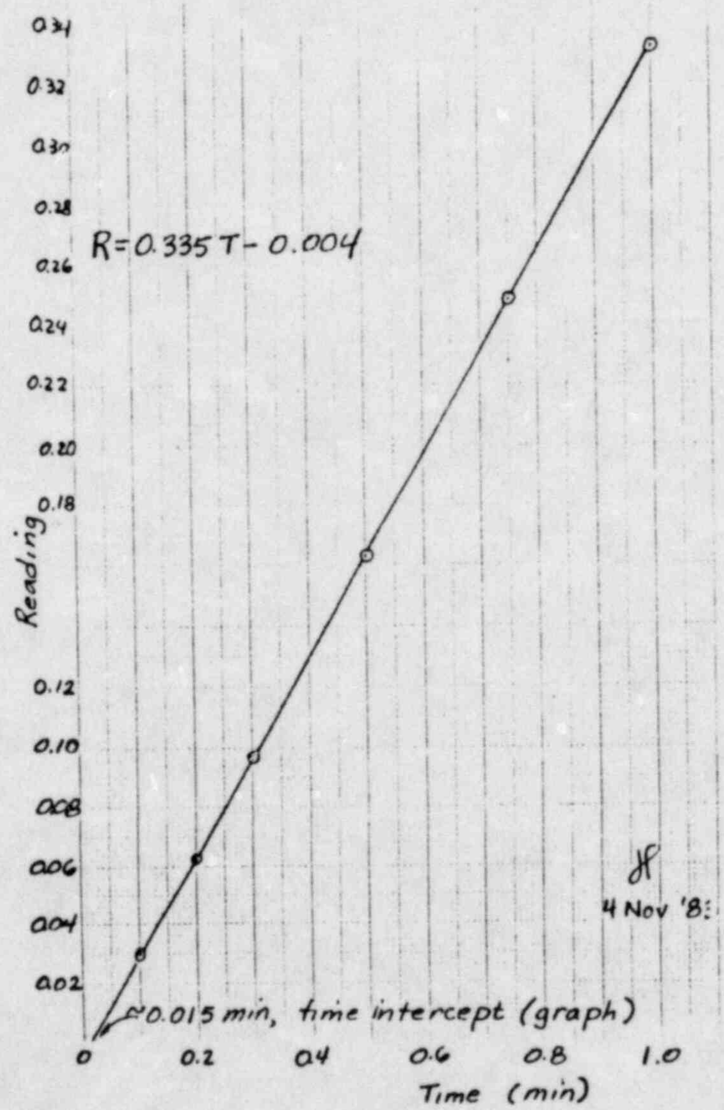
$= 175.87\ \frac{\text{rad}}{\text{min}}$ dose rate delivered (projected) to same pt with full phantom of water

Tray Factor° "rate" mode (set up as before)
reading $\bar{s}$ tray: 0.549 (R_3)
reading $\bar{c}$ tray: 0.525 (R_4)

$$\text{Tray factor} = \left(\frac{R_4 - R_3}{R_3}\right)100\% = \left(\frac{0.525 - 0.549}{0.549}\right)100\% = -4.37\%$$

* BSF calculated from measurements; calculations on page 37.

\+ f_{water} = 0.966 ; f_{muscle} = 0.957 from J & C, pg 736


R=0.335T-0.004
Reading
0.34
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.12
0.10
0.08
0.06
0.04
0.02
≈0.015 min, time intercept (graph)
0
0.2
0.4
0.6
0.8
1.0
Time (min)
4 Nov '83

In air Timer error and delay study

Average of sum readings of $n=5$ trials with 0.20 minute exposures set per trial (setup as before)

readings: 0.318 , 0.317

average: 0.3175 (R_2)

$$\epsilon = \frac{(R_1 - R_2)T}{R_2 - nR_1} = \frac{0.331583 - 0.3175}{0.3175-(5)0.331583}(1.00\,min)\left(\frac{60\,sec}{1.00\,min}\right)$$

$$\epsilon = -0.63040\ sec$$

(R_1, T from page 29)

(min) exposure setting	readings	average
1.00	see page 29	$0.33158\bar{3}$
0.75	0.248, 0.248	0.248
0.50	0.163, 0.163	0.163
0.30	0.0971, 0.09675	0.09693
0.20	0.0635, 0.0628	0.06315
0.10	0.02995, 0.03075	0.03035

using L.R.,

$$R = 0.335\,T - 0.004$$

when $R = 0$, $T = 0.012\ min = 0.716\ sec$ (timer error, calc. from eq)

from graph, $T_{intcpt} \approx 0.015\ min = 0.900\ sec$ (timer error, from graph)

In air Field size dependence (FSD) factors

Setup as before, with varying field sizes; "rate" mode used T = 25.8°C CP = 770.8 mm Hg

TPCF: 0.99868

Field size (cm^2)	reading	FSD (norm to ave 10x10 rdg)	FSD '82 (factors meas @ '82 calib)	Δ(%) $\Delta = \frac{'83 - '82}{'82}$
10 x 10	0.549	—	—	—
(min) 4.1 x 4.2	0.522	0.952	0.955	-0.31
6 x 6	0.532	0.970	0.973	-0.31
8 x 8	0.540	0.985	0.987	-0.20
12 x 12	0.554	1.010	1.011	-0.10
16 x 16	0.565	1.030	1.030	—
20 x 20	0.573	1.045	1.044	+0.10
25 x 25	0.579	1.056	1.052	+0.38
(max) 34.8 x 34.9	0.577	1.052	1.052	—
10 x 10	0.548	—	—	—
$\overline{10 \times 10}$	0.5485	1.000	1.000	—

In air   Chamber intercomparison

$10 \times 10\ cm^2$ field @ 80 cm SSD, 45 cm STD, probe centered in field @ 80.5 cm from source.

VAH Capintec / Farmer chm   CCF = 4.2821

T = 26.0°C   CP = 770.7 mm Hg   TPCF = 0.99948

exposure setting: 1.00 min

readings: 41.3, 41.4, 41.4, 41.4

average: 41.375

output in air : ave × TPCF × CCF × A_{eq} × f_{muscle} ÷ exposure setting

$= 41.375 \times 0.99948 \times 4.2821 \times 0.985 \times 0.957 \div 1.00\ min$

$= 166.92\ \frac{rad}{min}$ in air for $10 \times 10\ cm^2$ field @ 80 cm SSD (dose rate delivered to small mass of muscle tissue @ this position)

In air measurement extrapolated to dose rate in water phantom (details outlined on pg 29):

output in water (projected) = BSF × ave × TPCF × CCF × A_{eq} × f_{water} ÷ exp set

$$= \frac{1.0395 \times 41.375 \times 0.99948 \times 4.2821 \times 0.985 \times 0.966}{1.00\ min}$$

$= 175.15\ \frac{rad}{min}$ dose rate delivered (projected) to same pt with full phantom

Calculation of in air standard @ 80 cm SSD:

(1) outputs measured in air (pgs 29, 35) : $166.92\ \frac{rad}{min}$
    $168.13\ \frac{rad}{min}$

(2) in water meas output, corr. for BSF (pg 37):
$176.42\ \frac{rad}{min} \div 1.0395 = 169.72\ \frac{rad}{min}$

ave = $168.26\ \frac{rad}{min}$

decay 19 days to 15 Nov 1983:

$$\dot{D} = \left(168.26\ \frac{rad}{min}\right) e^{-\frac{\ln 2}{5.26\,y} \times \frac{1\,y}{365\,d} \times 19d} = 167.11\ \frac{rad}{min}$$

(check: From pg 28, $174.61\ \frac{rad}{min} \div 1.0395 = 167.97\ \frac{rad}{min} \Rightarrow -0.51\%\ \Delta$)

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In water Calibration

$10 \times 10\ cm^2$ field @ 80 cm SSD, 45 cm STD

probe centered in field @ depth of maximum dose (6.5 mm) in water

B Keithley / Farmer chm #152 CCF = 538.6

T_w = 24.0 °C CP = 770.6 mm Hg TPCF = 0.99293

exposure setting: 1.00 minute

readings: 0.347, 0.348, 0.347, 0.347

average: 0.34725

output in water: ave × TPCF × CCF × C_λ^* ÷ exp set

$= 0.34725 \times 0.99293 \times 538.6 \times 0.95 \div 1.00\ min$

$= 176.42\ \frac{rad}{min}$ in water for $10 \times 10\ cm^2$ field @ 80 cm SSD, @ d_{max} = 6.5 mm depth

"rate" mode reading: 0.573

Backscatter Factor

(1) $\frac{\text{ave "integrate" mode rdg in } H_2O \times TPCF_{H_2O} \text{ (pg 37)}}{\text{ave "integrate" mode rdg in air} \times TPCF_{air} \text{ (pg 29)}}$

$= \frac{0.34725 \times 0.99293}{0.331583\overline{3} \times 0.99868} = 1.041$

(2) $\frac{\text{ave "rate" mode rdg in } H_2O \times TPCF_{H_2O} \text{ (pg 37)}}{\text{ave "rate" mode rdg in air} \times TPCF_{air} \text{ (pg 29)}}$

$= \frac{0.573 \times 0.99293}{0.549 \times 0.99868}$ 1.038

use ave of (1) & (2) = 1.0395 (+ 0.33% from std value (BJR) of 1.036)

* C_λ from ICRU 14 for Co-60: $C_\lambda = 0.95$ defined as R to rad conversion in water (table, pg 9); meas. depth is d_{max}, not the recommended 5 cm depth ([illegible])

[redacted]

28 OCT'83 | Full Calibration

In water   Verification of percent depth dose (PDD)

set up as before, c̄ probe centered in field (sizes as indicated) @ varying depths.

T_w = 24.0°C   CP = 770.7 mm Hg   TPCF = 0.99280

(T_w, CP remained constant throughout verification)

field size (cm²)	depth (cm)	"rate" mode reading	PDD, norm to 10x10 cm² field rdg @ dmax	posted PDD	Δ (%) Δ = (posted - meas) / posted
4.1 x 4.2 (minimum)	0.7 (dmax)	0.535	93.4	93	0.4
	5	0.402	70.2	69	1.7
	10	0.2725	47.6	46	3.5
	15	0.1815	31.7	31	2.3
	20	0.1215	21.2	20	6.0
6 x 6	0.68 (dmax)	0.551	96.2	96	0.2
	5	0.423	73.8	74	-0.3
	10	0.294	51.3	51	0.6
	15	0.199	34.7	35	-0.9
	20	0.135	23.6	23	2.6
10 x 10	0.65 (dmax)	0.573	100.0	100	—
	5	0.456	79.6	79	0.8
	10	0.3275	57.2	57	0.4
	15	0.229	40.0	40	—
	20	0.159	27.7	28	-1.1
14 x 14	0.6 (dmax)	0.592	103.3	103	0.3
	5	0.476	83.1	83	0.1
	10	0.351	61.3	61	0.5
	15	0.251	43.8	44	-0.5
	20	0.178	31.1	32	-2.8

28 OCT '83 Full Calibration

In water verification of PDD, cont.

field size (cm²)	depth (cm)	"rate" mode reading	PDD, norm to 10x10 cm² field rdg @ dmax	posted PDD	Δ (%) $\Delta = \left(\frac{\text{posted-meas}}{\text{posted}}\right)$
20 x 20	0.55 (dmax)	0.615	107.3	107	0.3
	5	0.499	87.1	86	1.3
	10	0.375	65.4	65	0.6
	15	0.275	48.0	48	—
	20	0.198	34.6	35	-1.1
34.8 x 34.9 (maximum)	0.4 (dmax)	0.647	112.9	109	3.6
	5	0.516	90.1	90	0.1
	10	0.396	69.1	69	0.1
	15	0.297	51.8	52	-0.4
	20	0.218	38.0	37	-2.6

28 OCT '83 Full Calibration

In water Wedge transmission factors

set up as before, c̄ probe centered in wedged field @ depth = 6.0mm (≈ dmax for all open fields measured). Average reading (calculated from readings measured under opposing wedge positions) used to determine transmission factors (WTF: normalized to identical openfield @ given depth; TF*: normalized to 10x10 cm² open field @ given depth). T_w = 24.0°C CP: 770.8 mm Hg TPCF = 0.99267 (T_w, CP remained constant throughout measurements).

fieldsize (cm²) (wedge size)	wedge 4°	Coll 4°	"rate" mode reading	WTF, norm to identical openfield rdg @ given depth	TF*, norm to 10x10 cm² open field rdg @ given depth	TF* meas in 1982 full calibration	Δ(%) Δ = ('83-'82)/'82
10 x 10	open	270	0.57375 (average)	1.000	1.000	1.000	—
10w x 10 (10w x 15)	30°	270	0.410				
		90	0.411				
			>0.4105	0.715	0.715	0.717	-0.3
	45	270	0.333				
		90	0.334				
			>0.3335	0.581	0.581	0.582	-0.2
	60	270	0.240				
		90	0.240				
			>0.240	0.418	0.418	0.413	1.2
8 x 8	open	90	0.563	1.000	0.981	—	—
8w x 8 (8w x 15)	30	270	0.426				
		90	0.426				
			>0.426	0.757	0.742	0.743	-0.1
	45	270	0.353				
		90	0.354				
			>0.3535	0.628	0.616	0.617	-0.2
	60	270	0.266				
		90	0.266				
			>0.266	0.472	0.464	0.463	0.2
6 x 6	open	270	0.550	1.000	0.959	—	—
6w x 6 (6w x 15)	45	270	0.369				
		90	0.370				
			>0.3695	0.672	0.644	0.647	-0.5
	60	270	0.305				
		90	0.306				
			>0.3055	0.554	0.531	0.532	-0.2

Calculation of Posted Outputs 90 cm SSD

(1) Inverse square from 80cm SSD data:

in air (pgs 29, 35) extrapolated to water: $175.87 \frac{rad}{min}$

$175.15 \frac{rad}{min}$

in water (pg 37) $176.42 \frac{rad}{min}$

ave = $175.81 \frac{rad}{min}$

$$175.81 \frac{rad}{min} \left(\frac{80.5}{90.5}\right)^2 = 139.11 \frac{rad}{min}$$

in water for $10 \times 10 cm^2$ field @ 90cm SSD @ d_{max} depth on 28 Oct 1983

(2) Calibration @ 90cm SSD data:

in water (pg 45) $138.21 \frac{rad}{min}$

average (1) & (2) = $138.66 \frac{rad}{min}$ in water for $10 \times 10 cm^2$ field @ 90 cm SSD, d_{max} depth 28 October 1983

decay 19 days to 15 November 1983:

$$\dot{D} = \left(138.66 \frac{rad}{min}\right) e^{-\frac{\ln 2}{5.261 y} \cdot \frac{1 y}{365 d} \cdot 18 d} = 137.71 \frac{rad}{min} \quad (\bar{s}\ \text{tray})$$

−4.405% for reduction in transmission by tray (pg 45):

$$\left(137.71 \frac{rad}{min}\right)(0.95595) = 131.65 \frac{rad}{min} \quad (\bar{c}\ \text{tray})$$

Posted Outputs (posted 1 Nov 1983)

90 cm SSD

$10 \times 10 cm^2$ field (45 cm STD); outputs are dose rates @ d_{max} in tissue* for 15 Nov 1983

no tray: $137.5 \frac{rad}{min}$

tray: $131.5 \frac{rad}{min}$

* assumed water-equivalent (~ 1.0% diff from J & C f-factor comparison

18 OCT '83 | Full Calibration

<u>In water</u> <u>Calibration @ 90 cm SSD</u>

<u>10 x 10 cm² field @ 90 cm SSD, c̄ 45 cm STD</u>; probe centered in field @ depth of maximum dose (<u>6.0 mm</u>) in water

<u>BKeithley / Farmer chm #152</u> <u>CCF = 538.6</u>

T_w = <u>24.0°C</u> CP = <u>771.2 mmHg</u> TPCF = <u>0.99215</u>

exposure setting : <u>1.00 min</u>

readings : <u>0.272, 0.273, 0.272, 0.272</u>

average : <u>0.27225</u>

<u>Output in water</u> = <u>ave x TPCF x CCF x C_λ ÷ exposure setting</u>

= 0.27225 x 0.99215 x 538.6 x 0.95 ÷ 1.00 min

= <u>138.21 $\frac{rad}{min}$</u> <u>in water for 10 x 10 cm² field @ 90 cm SSD @ d_{max}</u> = 6.0 mm depth

<u>Tray factor</u> "rate" mode (set up as above, c̄ 90 cm SSD)

reading s̄ tray : <u>0.450</u> R_1

reading c̄ tray : <u>0.430</u> R_2

$$\text{Tray factor} = \left(\frac{R_2 - R_1}{R_1}\right)100\% = \left(\frac{0.430 - 0.450}{0.450}\right)100\% = \underline{-4.44\%}$$

from tray factor calculation, pg 29, tray factor = <u>-4.37%</u>

use average tray factor = <u>-4.405 %</u>

Calculation of Outputs @ 120 cm SSD

(1) inverse square from 80 cm SSD data in air extrapolated to water:

$$\left(175.87\,\frac{rad}{min}\right)\left(\frac{80.5}{120.5}\right)^2 = 78.49\,\frac{rad}{min}$$

$$\left(175.15\,\frac{rad}{min}\right)\left(\frac{80.5}{120.5}\right)^2 = 78.17\,\frac{rad}{min}$$

in water: $\left(176.42\,\frac{rad}{min}\right)\left(\frac{80.5}{120.5}\right)^2 = 78.73\,\frac{rad}{min}$

(2) inverse square from 90 cm SSD data

$$\left(138.21\,\frac{rad}{min}\right)\left(\frac{90.5}{120.5}\right)^2 = 77.96\,\frac{rad}{min}$$

average (1) & (2) = $78.34\,\frac{rad}{min}$ in water for $10 \times 10\,cm^2$ field @ 120 cm SSD, @ dmax depth, 28 Oct 1983

decay 19 days to 15 Nov 1983:

$$\dot{D} = \left(78.34\,\frac{rad}{min}\right)e^{-\frac{\ln 2}{5.261y}\cdot\frac{1y}{365d}\times 19d} = 77.80\,\frac{rad}{min}$$

($\bar{s}$ tray)

−4.405% (assume for mantle tray factor) for transmission reduction by tray (pg 45):

$$\dot{D} = (0.95595)\,77.80\,\frac{rad}{min} = 74.37\,\frac{rad}{min}$$ ($\bar{c}$ tray)