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SHONKA CHAMBER CALIBRATIONS PROCEDURE

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ABSTRACT

This report describes the operational procedure for using Shonka type air-ionization chambers for calibrating radiation fields at the Lawrence Livermore Laboratory Hazards Control Dosimetry Calibrations Laboratory.

DESCRIPTION

The Shonka chambers described are air ionization chambers made of air-equivalent plastic spherical outer walls and center air-equivalent plastic collecting electrodes (see Fig. 1). When an electric field is applied, the current produced determines the rate of ionization within the chamber. A vent hole in each chamber allows equalization of pressure resulting in an output that is dependent upon temperature and pressure. Correction factors must be applied. An integrating electrometer determines the current.

CHAMBER CAPABILITIES

The Calibration Laboratory has three Shonka chambers. The spherical collecting volumes of two are 3 cm³ and the volume of the third is 85 cm³ (see Fig. 2). One of the small chambers has a 1/4-mm-thick wall and is calibrated for x rays and low-energy gammas ranging in energy from 40 to 200 keV. The second small-volume chamber and the large chamber both have 2.5-mm-thick walls and are calibrated for ¹³⁷Cs and ⁶⁰Co. Both can be used reliably for energies as low as 200 keV. The lower limit of detectability for the small-volume chambers is around 0.5 R/h, and for the large chamber is 50 mR/h. Table 1 summarizes the volumes and ranges of the three Shonka chambers.

Fig. 1. Internal view of Shonka ionization chamber.

Fig. 2. Shonka ionization chambers.

Table 1. Air-equivalent Shonka chambers.

Chamber No.	Volume (cm ³)	Wall thickness (mm)	Minimum rate (R/h)	Calibration keV energies		Range (keV)
154	3	0.25	0.5	38	117	40-200
378	3	2.5	0.5	662	1250	200-2000
10	85 ^a	2.5	0.5	662	1250	200-2000

^aBest measurement of collecting air volume. People at NBS estimated volume at 105 cm³, and this erroneous volume appears on the NBS calibration data.

INSTRUMENT CONFIGURATION

The Shonka chamber signal coming from the center cable (the one with a BNC connector attached) is connected to the Victoreen Dynamic Capacitor Electrometer input. As the charge collects on a given scale, an appended digital voltmeter reads the percent of full scale and triggers a timer when 10% of full scale is reached. The timer is an Elron scaler-timer set to read in tenths of seconds. The digital voltmeter logic also sends a stop signal to the timer when 90% of full scale is reached, resulting in a measurement of the time taken to charge the electrometer to 80% of its full-scale value. Figure 3 shows the electronics. Make the high-voltage connection to the lead coming from the sphere and connect to either of the +300-V output from a Philbrick power supply.

CAUTION: The 300 volts are applied to the spherical electrode which must not be shorted to metal conductors. Apply voltage after positioning the chambers and remove the voltage immediately after completing data accumulation.

PROCEDURE

Accumulate at least three readings when the chamber is biased positively. Choose a scale where the timer is activated for at least 100 s. Stop

Fig. 3. Electronics. (a) Integrating electrometer, (b) timer, (c) digital voltmeter and reset control to timer, (d) 300-V power supply, and (e) signal cable patch from experimental cells.

and change the polarity so that the outer sphere is charged to negative 300 V. Allow approximately 3 min to equilibrate and accumulate three more readings. Average the positive readings and the negative readings separately and then average the two together. If the positive and negative readings vary by greater than 5% from the combined average, it is recommended that the cable connectors be cleaned and perhaps that some of the patch cables be substituted to try to decrease the leakage current so that the averaged plus and averaged minus values will fall within 5% of the combined average.

CALCULATIONS

The measurement involves a change in voltage for a given change in time ($\Delta V/\Delta t$), whereas the National Bureau of Standards has calibrated the Shonka chambers in terms of Roentgen per coulomb. Therefore, we must multiply the input capacity by $\Delta V/\Delta t$ to get the rate of change of charge, where $Q = CV$. The equation is:

$$\text{Roentgen/min} = C \frac{\Delta V}{\Delta t} KF \times 60 \text{ s/min}$$

where K is the NBS calibration factor and $F = (273.15 + T)/273.15P$.

In the last equation, T is the temperature in degrees Celsius and P is the pressure expressed as a fraction of a standard atmosphere. The atmospheric pressure must be measured using the barometer in the control room and applying correction factors for temperature and gravity. The gravity correction is a constant and is -0.2 mm. Find the correction in Table 2 for the temperature. A sample calculation appears in Appendix A.

Table 2. Temperature correction table (to reduce the reading of the barometer to standard temperature).

Temperature (°C)	Observed reading of the barometer (mm)															
	480	500	520	540	560	580	600	620	640	660	680	700	720	740	760	780
	All corrections subtractive															
17	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.1	2.1	2.2
18	1.4	1.5	1.5	1.6	1.6	1.7	1.8	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.2	2.3
19	1.5	1.6	1.6	1.7	1.7	1.8	1.9	1.9	2.0	2.0	2.1	2.2	2.2	2.3	2.4	2.4
20	1.6	1.6	1.7	1.8	1.8	1.9	2.0	2.0	2.1	2.2	2.2	2.3	2.3	2.4	2.5	2.5
21	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.5	2.5	2.6	2.7
22	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.2	2.3	2.4	2.4	2.5	2.6	2.7	2.7	2.8
23	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.3	2.4	2.5	2.5	2.6	2.7	2.8	2.8	2.9
24	1.9	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.5	2.6	2.7	2.7	2.8	2.9	3.0	3.1
25	2.0	2.0	2.1	2.2	2.3	2.4	2.4	2.5	2.6	2.7	2.8	2.9	2.9	3.0	3.1	3.2
26	2.0	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.7	2.8	2.9	3.0	3.0	3.1	3.2	3.3
27	2.1	2.2	2.3	2.4	2.5	2.6	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.3	3.4
28	2.2	2.3	2.4	2.5	2.6	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6
29	2.3	2.4	2.5	2.6	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7

ACCURACY

The overall accuracy of the NBS calibration value is believed to be within 2%. The accuracy of the ion current measurement lies within a few tenths of a percent.

APPENDIX A: SAMPLE CALCULATION

Data for ^{60}Co

Measured T = 21.3°C

Barometer reading = 747.5 mm

Victoreen 475 on 0.3-V range in integratemode

+300 V bias 80.4 s

80.5

80.6

Average 80.5

-300 V bias 78.9

79.1

79.1

Average 79.0

Overall average 79.8 ± 0.75 (less than 1%)

C = 947×10^{-12} Farads (measured by Electronics Department)

ΔV = 80% scale = 0.24 V

Δt = 79.8 seconds

corrected pressure = reading 747.5 - (0.2 + 2.7) = 744.6

$$P = \frac{744.6}{760} = 0.9797$$

Find Roentgens/minute

$$R/\text{min} = C \frac{\Delta V}{\Delta t} \cdot K F \cdot \frac{60 \text{ sec}}{\text{min}}$$

$$\text{where } F = \frac{(273.15 + T)}{273.15 P},$$

$$\text{and } P = \frac{\text{corrected pressure}}{760 \text{ mm}}$$

$$R/\text{min} = (947 \times 10^{-12} \text{ Farads}) \frac{0.24 \text{ V}}{79.8 \text{ s}} \cdot 9.027 \times 10^8 \text{ R/F}$$

$$\cdot \frac{273.15 + 21.3}{273.15 \times 0.9797} \cdot \frac{60 \text{ sec}}{\text{min}}$$

$$= 0.1697 = 169.7 \text{ mR/min}$$