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NOTE ON THE GUARDED-FIELD X-RAY IONIZATION CHAMBER

By Lauriston S. Taylor and George Singer

ABSTRACT

The number of guard wires in the NBS guarded-field ionization chamber has been reduced from twelve to eight, and the other attendant alterations necessitated thereby are given. It is shown that strictly uniform potential distribution between guard wires is not essential and that ionization between guard wires, therefore, produces no spurious effects within the chamber. Coin-gold diaphragms have replaced those used prior to 1931. Coplanarity of electrodes is assured by making them as a single unit.

CONTENTS

I. NUMBER OF GUARD WIRES

The rather extensive adoption of the Bureau's design of an X-ray ionization chamber [1] makes it desirable to describe some minor improvements made since publishing the description; and, at the same time, to clear up some misapprehensions as to the adequacy of the particular design of chamber which has been chosen. For instance, two cases have come to our attention in which an insufficient knowledge of the theory [2] of the guarded-field chamber has led to errors of 2 or 3 percent. On the other hand, out of a number of such chambers calibrated in this laboratory, only one has been found in error by an amount substantially greater than that fixed by the experimental tolerances.

When preparing to make an international comparison of standards in 1931, we reduced the number of guard wires from the previous selection of twelve to eight.[3] This was principally for use in European

[1] Lauriston S. Taylor and George Singer, BS J. Research **5**, 507 (1930) RP211.

[2] C. Snow, BS J. Research **1**, 513 (1928) RP17.

[3] Lauriston S. Taylor, BS J. Research **8**, p. 9 (1932) RP397. This particular 8-wire chamber has been preserved intact for a reference standard.

laboratories to facilitate the alignment of the chamber in the radiation beam. From the theory of the guarded field, this change called for a lengthening of the lead box surrounding the plate system, in order to retain field disturbance at the center of the chamber within the desired limits.

Figure 1 shows a plot of the measured ionization current, using the 8-wire chamber, as a function of the spacing between the guard wires and end plates. It is evident that the field disturbance effectively disappears with the spacing greater than 5 cm. As a safety margin,

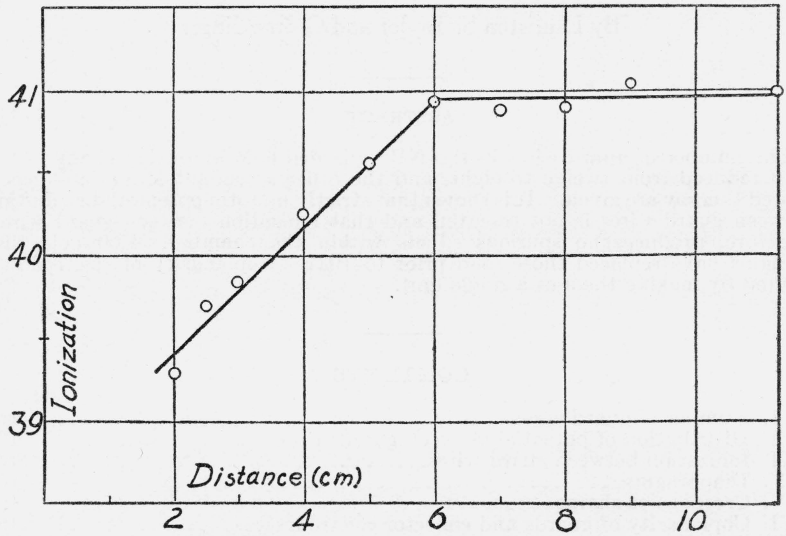

FIGURE 1.—*Measured ionization current as a function of the spacing between the guard wires and the grounded case.*

there is always employed a 7-cm spacing on the 8-wire chambers, whereas a 4-cm spacing had been found sufficient on the 12-wire chambers.

Similar studies were made with a guarded-field chamber designed for low-voltage radiations (4 to 90 kv)[4] having 4 guard wires 1 cm apart. In that case, a separation of 3 cm between guard wires and end plates was found sufficient.

II. DISTRIBUTION OF POTENTIAL BETWEEN GUARD WIRES

It has been found by trial that exactly equal potential differences from one guard wire to the next is not strictly necessary. Figure 2 shows a plot of the measured ionization current as the potential difference between the central pair of guard wires is changed from 0 to 2 times its normal value in the 8-wire chamber. In this, it is seen that

[4] L. S. Taylor and C. F. Stoneburner, BS J. Research 9, 769 (1932) RP505.

a difference of ± 3 percent from the normal potential difference causes a change of 0.1 percent in the measured ionization current. It is, of course, a very simple matter to maintain the potential distribution between guard wires to within 0.5 percent of the normal value. When using graphite or similar resistors in the potential divider, it is necessary only that their resistance remain very constant during a single determination.

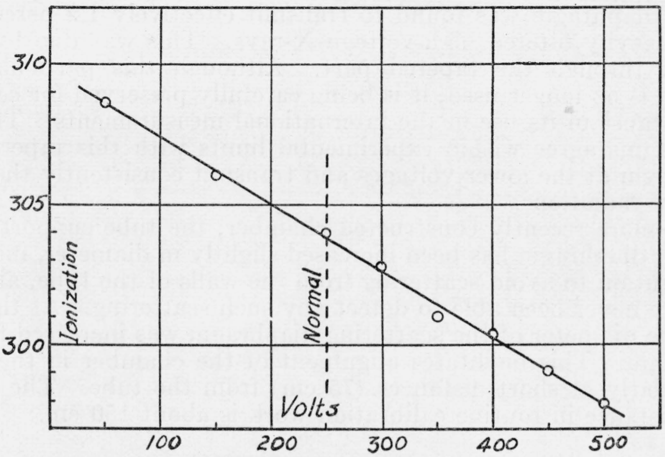

FIGURE 2.—*Measured ionization current as a function of the potential difference between the central pair of guard wires.*

III. IONIZATION BETWEEN GUARD WIRES

It has been suggested [5] that the relatively intense ionization between the central pair of guard wires might be a possible source of difficulty in a guarded-field ionization chamber. Such localized ionization can have two effects—one to introduce a slight further transverse inhomogeneity in the ion density about the defined X-ray beam, and the other to cause an effective change of resistance between the central guard wires, thus disturbing the field within the chamber. The matter of uneven ion density is of no importance for ordinary radiation intensities, provided that air absorption is negligible, since the measured ionization current is solely a function of the radiation flux density at the limiting diaphragm.[6] Since the resistance between successive guard wires is conveniently chosen at 0.2 to 0.5 megohm, the change in effective resistance due to the air conductivity is less than 0.001 percent. However, as noted above, the field at the center of the chamber is very insensitive to changes up to 5 percent in the guard-wire potentials and hence field disturbance caused by ionization between wires is negligible.

IV. DIAPHRAGMS

Following the international comparison, our chambers have been fitted with coin-gold (90 Au, 10 Cu) limiting diaphragms. This was

[5] W. V. Mayneord, Brit. J. Rad. **6**, 205 (1933).
[6] L. S. Taylor, BS J. Research **3**, 807 (1929) RP119.

decided upon when it was found that lead or lead alloy diaphragms could neither be made nor measured with sufficient accuracy. The gold diaphragms,[7] which are 4 mm thick, have been found to transmit through their boundary walls less than 0.1 percent of a heavily filtered 195-kv beam of radiation passing normally through the 8-mm aperture. In making the international comparisons, a slightly tapered lead-cadmium alloy diaphragm was used. As compared with the effective cross section of the aperture at low voltage, the tapered wall of this diaphragm was found to transmit effectively 1.2 percent too much heavily filtered high-voltage X-rays. This was due to transmission through the tapered part. Although this particular diaphragm is no longer used, it is being carefully preserved for comparison, because of its use in the international measurements. The gold diaphragms agree within experimental limits with this tapered-wall diaphragm at the lower voltages and transmit consistently the entire range of radiations.

In a more recently constructed chamber, the tube supporting the limiting diaphragm has been increased slightly in diameter, merely as a precaution to avoid scattering from the walls of the tube, although we have never been able to detect any such scattering. At the same time the diameter of the scattering diaphragm was increased from 12 to 14 mm. This facilitates alignment of the chamber in the beam, particularly at short distances (75 cm) from the tube. The normal tube distance in routine calibration work is about 150 cm.

V. CREEPAGE OF CHARGE

In the chambers now used, the potential dividing resistances are mounted on a hard-rubber panel just above the guard wires. When using a very sensitive detector system of low capacitance (FP–54, electrometer tube, 15 $\mu\mu$f), we have occasionally been troubled by charges induced on the collector electrode, apparently from creepage along the rubber surface. This usually arises in damp weather, but might be avoided by a different mounting of the resistors.

VI. COPLANARITY OF GUARDS AND COLLECTOR ELECTRODES

Another source of error has been found to lie in the failure to secure perfect alignment in the same plane of the guard and collector electrodes. To avoid this, these three electrodes have been mounted in a separate rigid unit, which can be readily detached from the rest of the system for inspection and adjustment. In this connection, the collector electrode is pulled tightly against the supporting yokes and ambers, after which the whole face of the assembly is first machined, and then ground and polished as a single unit—thus assuring accurate coplanarity of the faces. This construction also facilitates the accurate measurement of the collector width and air gaps, since the unit can be easily placed upon the table of a micrometer microscope.

[7] For description, see page 772 BS J. Research 9 (1932), RP505.

VII. TEMPERATURE OF CHAMBER

Temperature correction for a standard X-rayionization chamber is roughly ⅓ percent per degree centigrade. Heat dissipation inside the guarded-field chamber by the potential divider when operating at 2,100 volts is slightly less than 1 watt. To be certain that this did not influence the air temperature within a sealed chamber, simultaneous temperature measurements were made at the center and the outside of the chamber over a long period of time. A maximum difference of about 0.2° C was noted.

VIII. CURRENT COMPENSATION

Attention is called to another source of error which may be encountered in using any of the standard null methods of current measurements. It is of the "personal-error" type caused by failing to maintain the collector system sufficiently near ground potential during the balancing process. We have found, depending upon the operator and the voltage sensitivity of the electrometer, that a given operator tends to over-balance or under-balance consistently during the exposure time. This usually can be avoided by increasing the voltage sensitivity to the point just below which operation becomes troublesome from electrical and mechanical instability. For example, in one standard tested, a consistent potential difference of 0.2 volt between guard and collector electrode was found to introduce an error of 2 percent in the current measurement. This is, of course, an extreme effect since, with experience, one tends to balance out the deviations.

WASHINGTON, November 6, 1935.