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Arthur W. Erskine
Coe College

Scott W. Smith Jr.
Coe College

THE RELATIVE VALUES OF THE SELENIUM CELL AND THE IONIZATION METHODS OF MEASURING X-RAYS IN ROENTGENOTHERAPY

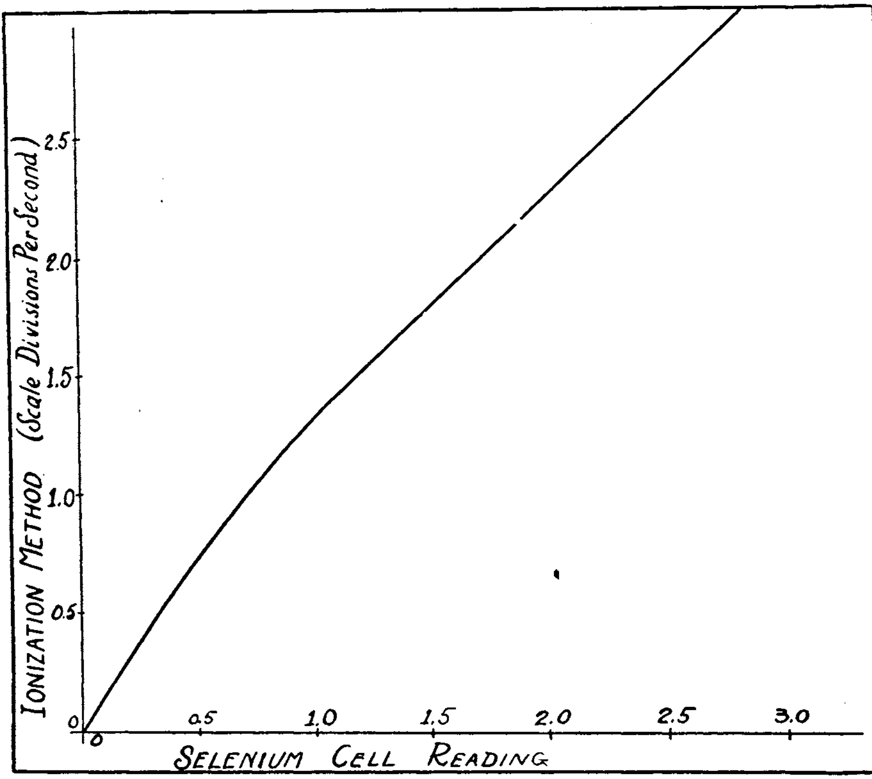
ARTHUR W. ERSKINE AND SCOTT W. SMITH, JR.

The two facts which the roentgenologist must know about a beam of x-rays which he is going to use are its penetrating power and its intensity. The penetrating power of a beam of x-rays produced by any set of technique factors can be determined from charts prepared from the experience of many investigators, including the authors, who have produced a set of 160 charts for that purpose. The charts are drawn actual size and show the distribution of x-rays in water with all the variations in technique commonly used in therapy, — water being used as a medium because the absorption and scattering of x-rays in water is practically the same as in tissue. The use of the charts is simple and direct. A cross-section of the patient is made on transparent paper showing the position of the region to be radiated. The cross-section is then applied to the chart and the percentage of the surface radiation reaching any point can be read through the paper from the chart. This not only shows the distribution of the radiation but forms a means of estimating the number of areas that must be radiated in order to deliver a definite percentage of the surface radiation to a given position in the patient.

The intensity of the surface radiation, however, cannot be predicted with any great certainty from preliminary measurements of the technique factors because of their multiplicity. Because in modern x-ray therapy, especially of malignant disease, dosage often approaches the limit of skin tolerance, and because of the disastrous results which may follow an accidental error in measuring one or more of the technique factors, it is desirable that the rays be measured as they reach the patient.

Various instruments making use of the ionization method have been designed to meet this need. These instruments, consisting essentially of an ionization chamber and a gold leaf electrometer, are reasonably accurate if an average is taken of several readings and as the work of Kroenig and Friedrich, Duane, Milwee, Ernst and others has shown, express the intensity of x-rays in terms bearing a definite relationship to the physiological effect. They have the disadvantages of being cumbersome and delicate, and of requiring considerable time for making measurements.

The selenium cell instrument consists essentially of a selenium cell made of a layer of selenium between two conducting plates, and a Wheatstone bridge for measuring the change in resistance



of the selenium upon exposure to x-rays. The bridge is so arranged that after a balance has been obtained with the cell disconnected, the slight change in resistance produced by x-rays is shown by the deflection of the galvanometer needle. An instantaneous reading is thus obtained by making a single slight adjustment. The scale on the galvanometer is calibrated into arbitrary units.

Since the practical value of any instrument to be used as a final check depends upon its being so simple and rapid that it can and will be used to measure every dose of radiation given in a busy laboratory, the experiments described in the following paragraphs were undertaken to determine if the convenient selenium cell method of measurement is sufficiently accurate, and if its measurements can be expressed in terms of the physiological effect.

A series of measurements was made simultaneously with the selenium cell and the ionization methods to determine if possible whether a definite relationship exists between the two. The measurements were made in air with the ionization chamber and the selenium cell side by side and using all the variations of the technique factors which vary the quality of the beam. The result was a large number of pairs of readings of the two instruments, each reading corresponding to some particular intensity. The pairs of readings each being a function of the same intensity and hence of each other were plotted. The graph of the two sets of readings is shown in the figure. In the table are shown the results obtained by averaging from 5 to 10 pairs of readings for each thirty different sets of technique factors.

Average Ionization Scale Divisions Per Second	Average Selenium Cell Readings	Average Ionization Scale Divisions Per Second	Average Selenium Cell Readings
7:70	9.20	1.02	0.70
5.26	5.50	0.80	0.66
3.64	3.20	0.72	0.58
3.44	3.20	0.82	0.58
2.94	2.77	0.50	0.39
2.04	2.60	0.50	0.34
2.16	2.30	0.46	0.32
2.10	1.90	0.54	0.32
1.88	1.62	0.32	0.25
1.56	1.07	0.30	0.21
1.28	1.06	0.32	0.21
1.14	0.85	0.34	0.20
0.94	0.76	0.22	0.15
0.94	0.74	0.20	0.14
1.06	0.73	0.14	0.13

Percentage of Error	Percentage of Total Number of Points
Zero %	30 %
1 %	14 %
3 %	13 %
5 %	10 %
6 %	7 %
8 %	13 %
9 %	4 %
10 %	3 %
Over 10 %	6 %

It is estimated from a study of the large amount of work done with the ionization apparatus that it will measure the intensity of x-rays within a five per cent error. From a study of the number of points falling on the smooth curve in the figure we find that 30% of the points fall on the curve; 67% have an error of 5% or less and 94% have an error of 10% or less. Considering the maximum error of the ionization readings to be 5% the selenium cell readings would have no greater error than the ionization readings. Further, the measurements were made regularly over a period of several months and include irregularities and changes in the instrument itself. The selenium cell method may therefore be considered reasonably accurate.

From a graph similar to the one shown in the figure especially prepared for each instrument or by supplying a correction factor it is possible to express the selenium cell measurements in terms of the ionization measurements. This is an advantage as a large amount of data has been compiled using ionization apparatus and the practitioner is accustomed to thinking and expressing the biological effect in terms of ionization measurements.

It cannot be said that the selenium cell method is ideal or that it fills all the requirements of a practitioner. However, it does furnish a means of determining with a fair degree of approximation the biological effect of a beam of x-rays in a simple, direct and rapid manner and will at least indicate if the beam differs radically from that which the practitioner wishes to use. This fact alone makes the instrument worthy of some consideration.

COE COLLEGE,
CEDAR RAPIDS, IOWA.