THE PHYSICAL FOUNDATION OF GRENZ-RAY THERAPY

OTTO GLASSER, PH.D.

Reprinted by special permission from RADIOLOGY, *Journal of the Radiological Society of North America, 18:713-725, April, 1932.*

About six years ago, Dr. Gustav Bucky invited me to work with him on the investigation of the physical and clinical foundations of over-soft roentgen rays, which he had just introduced into practical use. We attempted to determine the wave lengths of the soft rays used by Dr. Bucky and to devise practical methods of measuring the quality and quantity of these rays, publishing the results in various papers, including those in the *American Journal of Roentgenology and Radium Therapy*,[1] and also in Dr. Bucky's book.[2]

Although considerable progress has been made in the past few years[3] in the clinical application of Grenz rays, the physical foundations have essentially remained the same. In the following presentation, therefore, some of the old data will necessarily be repeated and the few new developments will be added.

During the past few years, the name "Grenz," or border, rays has been used more and more in the literature to designate roentgen-ray beams of an average wave length of about 1.5 to 2.5 Angstroms, or of half value layers of 0.015 to 0.03 mm. of aluminum. Although from the biologic and clinical points of view the term "borderline rays" has its justification, it must be emphasized here that physically these rays form only a small part of the large spectrum of roentgen rays which has been known for many years.

GRENZ-RAY APPARATUS

A Grenz-ray apparatus is shown in Fig. 1. The main transformer, the filament transformer, and the Grenz-ray tube are contained in a separate shock-proof box (*B*) which is suspended on a stand and can be easily adjusted. The tube acts as its own rectifier. The switchboard (*A*) contains the autotransformer and resistance control, a milliameter, a voltmeter, and also a water pump which forces water through the cooling device of the tube. One side of the transformer, usually that which supplies current to the water-cooled electrode, is grounded.

Well-known European types of Grenz-ray apparatus are manufactured by Siemens-Reiniger-Veifa, of Berlin; Sanitas, of Berlin; Koch and Sterzel, of Dresden; Seifert, of Hamburg, and Sommer, of

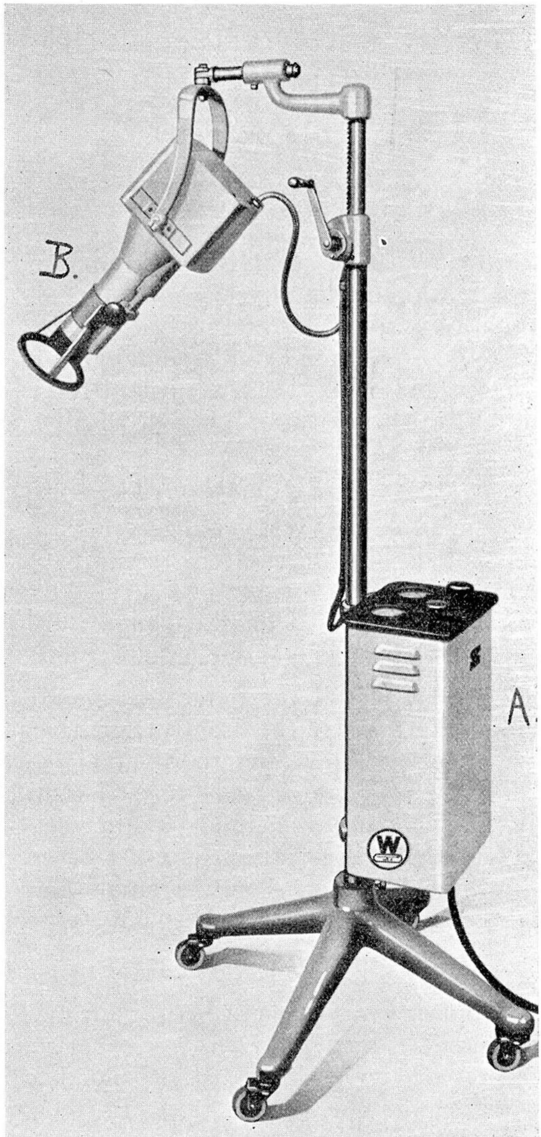

Fig. 1. Westinghouse Grenz-ray apparatus. (*A*) switchboard, (*B*) transformer and Grenz-ray tube.

Vienna. These types are all practically the same, that is, the control board, the transformer, and the tube are all mounted on one easily movable stand.

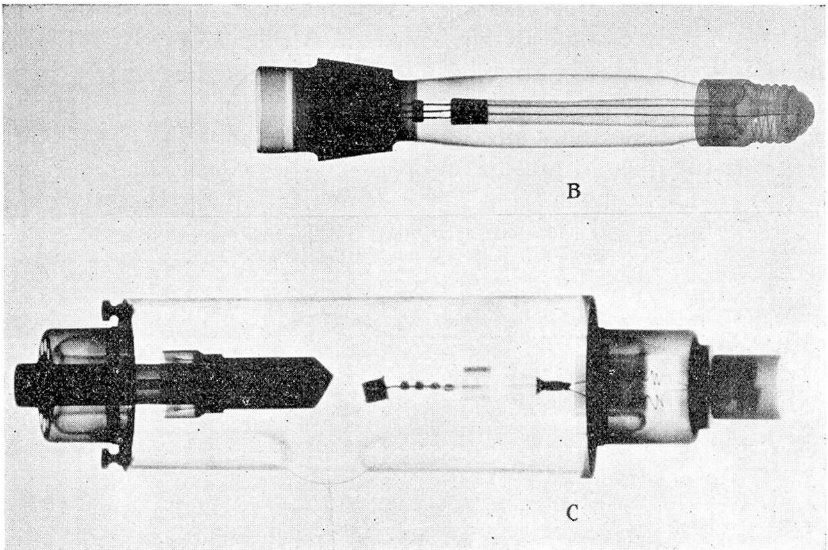

Fig. 2. (*B*) Muller Grenz-ray tube, (*C*) Siemens Grenz-ray tube.

Grenz-ray Tubes

In previous publications we described the commercial tubes (manufactured by C. H. F. Muller, of Hamburg, and by Simens-Reiniger-Veifa, of Berlin), which are still in use today (Fig. 2, B and C). We also described a tube made entirely of lithium glass, which was constructed in the laboratories of the Cleveland Clinic Foundation. At that time we called attention to the fact that this tube did not yet compare favorably with the commercial Grenz-ray tubes, since the transmission rate of the lithium glass used by us was less than that of the Lindemann glass used in the commercial tubes. We, therefore, abandoned the construction of lithium glass tubes and turned to another method in which we attempted to avoid the use of the Lindemann window. It must be remembered that the materials of which the Lindemann window is composed, namely, boron, beryllium, and lithium, are of low atomic weight and, therefore, easily permit the transmission of very soft rays. On the other hand, the Lindemann window must be rather thin (about 0.3 mm.) and, since it is slightly hygroscopic, it is not stable. Since it deteriorates in time unless it is carefully protected by a covering of lacquer, an attempt was made to obtain the same radiation transmission with a more stable window. Following the idea of the thin glass window used by Slack in his cathode-ray tube, we built a Grenz-ray tube with the same type of window.[4] The tube itself, with the exception of the window, is built on the same principles as that made by the C. H. F. Muller Company (Fig. 3). The window is a very thin bubble of glass which is drawn into a larger glass sphere. According to our tests, the filtering action is about the same as that of the Lindemann window of the Muller tube, but the glass window is more stable and does not deteriorate with time. This construction easily prevents damage to the window and also offers good resistance to the atmospheric pressure.

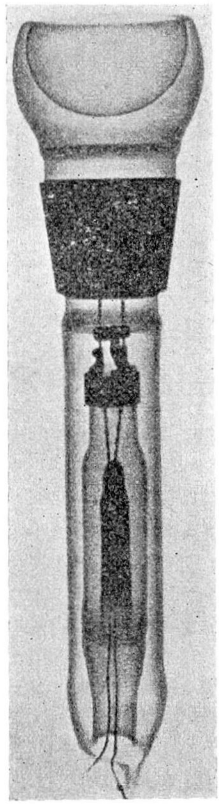

Fig. 3. Grenz-ray tube with Slack window.

Shortly after the construction of our tube and the publication of our article in *Strahlentherapie*, an advertisement of the Westinghouse X-ray Company appeared in the *Journal of the American Medical Association* (June 1931, XCVI, 7), describing a new Grenz-ray tube, built on the same principle as ours, on which scientists of the Westinghouse X-ray Company had been working independently for some time. This Westinghouse Grenz-ray tube (Fig. 4),

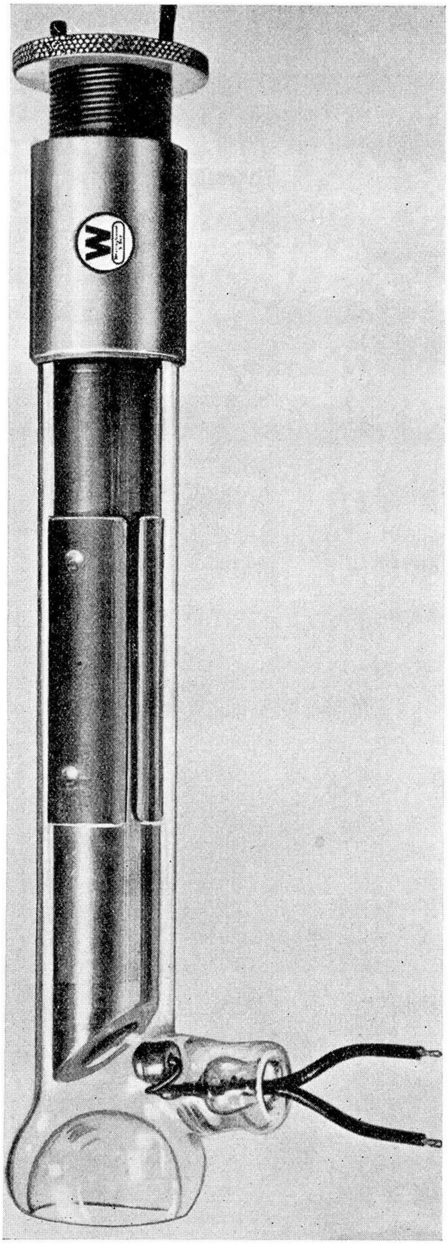

Fig. 4. Westinghouse Grenz-ray tube.

the Siemens, and the Muller tubes are the only commercial Grenz-ray tubes on the market at the present time.

SPECTRUM OF GRENZ RAYS

Grenz rays are roentgen rays of a wave length in the neighborhood of 2 A.U., which are produced by the special tubes just described. Because of the low potential used (around 10 K.V.), the spectrum is limited to about 1 A.U. at the short wave end. These short wave lengths have very characteristic properties, described in detail in earlier publications [1-8], which are important in therapy and must be discussed briefly here.

As Grenz rays are extremely soft, their quality and quantity depend very much upon the thickness of the glass or Lindemann glass window, and also upon the layer of air between the tube and the skin, or measuring instrument. The spectral distribution of the Grenz-ray beam, and therewith its quality, on the one hand, will change with various thicknesses of windows and with various focal skin distances; the relative intensities of Grenz-ray beams, on the other hand, will not follow the law of inverse squares of distance.

Curves of the spectral distribution of Grenz rays produced at various voltages as calculated by Kustner[9] are shown in Fig. 5.

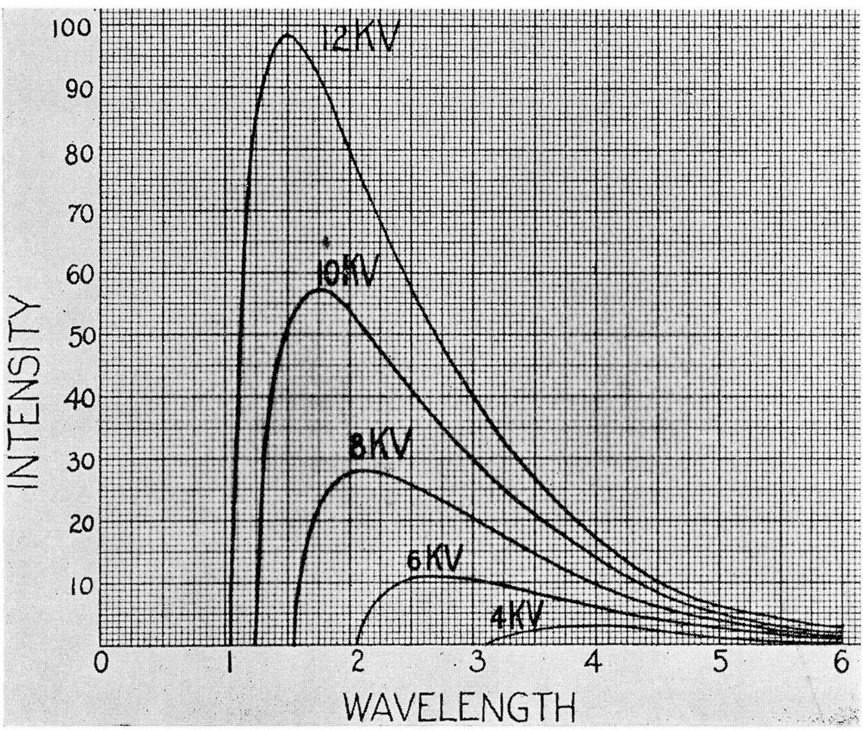

Fig. 5. Spectrum of Grenz-ray beams produced at various voltages (Kustner).

Additional spectral distributions of Grenz-ray beams have been reported elsewhere.[1 2 6 9] It is interesting to study the spectral distribution as well as the rapid decrease in intensity for decreasing voltages. The absorption of Grenz rays in a Lindemann window and in air can be calculated for various wave lengths by means of the following formula[9]:

$$\mu \text{ air} = 0.00331\,\lambda^3 + 0.00022$$
$$\mu \text{ Lindemann} = 5.0\,\lambda^3 + 0.04$$

where μ is the coefficient of absorption and λ the wave length in Angstroms. These absorption coefficients permit the calculation of the absorption of the window and of air for various wave lengths.

TABLE I

	Thickness of Lindemann windows in millimeters		
K.V.	0.04	0.20	0.40
6	40.7	0.074	0.013
8	118.0	34.3	0.14
10	256.0	100.0	49.2

These data show the great influence of the thickness of the tube window and air layers upon the qualitative and quantitative distributions of the rays. It follows, therefore, that in order to obtain a correct estimate of the quality and quantity of Grenz rays at a given point, for instance, for the application of a certain dose, it is necessary that this determination be made at the point of the application of the rays. We shall, therefore, employ the half value layer in aluminum to indicate the radiation quality, and the number of roentgen units per minute to indicate the intensity of the radiation. In addition we shall specify the kilovoltage, the milliamperage, the tube, the target material, and the focal distance.

Determination of Quality of Grenz Rays

(*A*) *Indirect Method.* As we have just stated, it is advisable to supplement the direct method of determination of quality by the so-called indirect method, which consists in giving the secondary voltage and current and specifying the tube, target material, and focal skin distance used. The switchboards of all types of Grenz-ray apparatus mentioned above are equipped with a kilovolt meter, that is, a voltmeter which is connected across the primary of the transformer. The voltmeters are calibrated in kilovolts in the factory by various methods. Whenever feasible, it is advisable to recalibrate these meters from time to time by means of sphere gaps or spark gaps. Better than sphere gaps are electrostatic voltmeters which are reliable and can be easily procured for the voltages

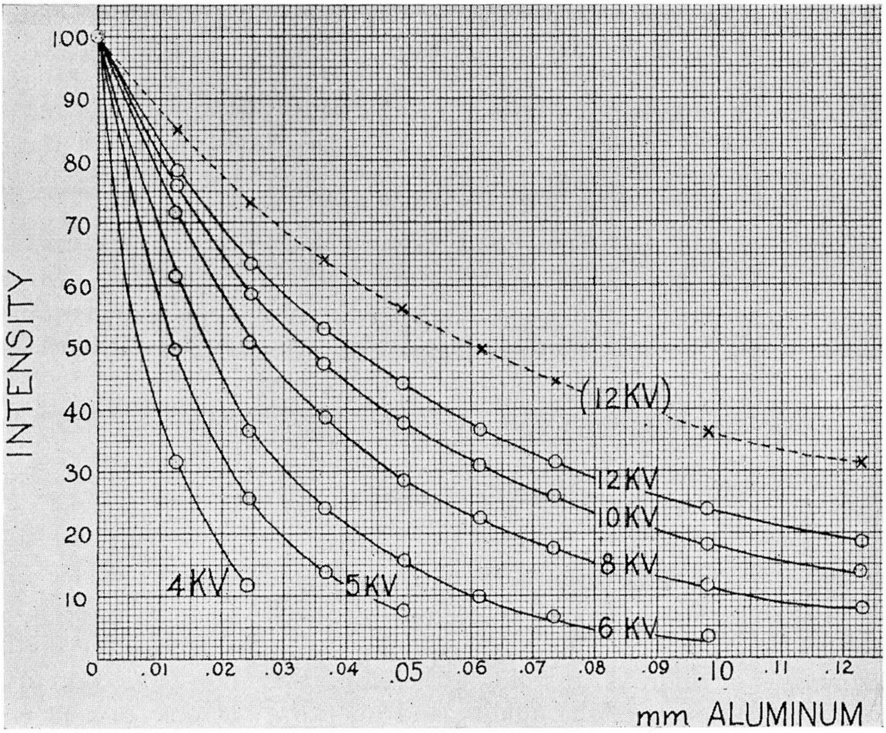

Fig. 6. Absorption curves for Grenz rays produced at various voltages.

used in Grenz-ray therapy. It is not sufficient, however, to connect the gap right across the terminals of the Grenz-ray tube since in practically all Grenz-ray apparatus the negative phase of the current is not suppressed. This negative phase usually is higher than that which reaches the tube and must, therefore, be excluded by means of a valve tube which must be included in the secondary circuit connected in series with the sphere gap. In order to avoid mistakes, secondary voltages should always be given in peak and not in effective voltages. The secondary current is read on a milliamperemeter which is also mounted on the switchboard of the Grenz-ray apparatus.

(*B*) *Direct Method.* In addition to the data described in the preceding paragraphs it is advisable to indicate the radiation quality by direct means. A number of years ago we suggested the use of the half value layer in aluminum to specify radiation quality in Grenz-ray therapy. This half value layer can be determined satisfactorily by means of the ionization dosimeter which will be described later. In our measurements we used pure aluminum foil of

0.0125 mm. thickness as an absorbent material. Cellophane, as well as other substances, has been suggested for this purpose. We found, however, that aluminum was superior to other materials since it can be obtained in uniform thickness and does not show the variations in absorption due to impurities or irregularities in composition inherent in most other materials. Furthermore, some of the other materials are hygroscopic and, therefore, change with time.

Complete absorption curves on Grenz rays produced at various voltages have been described,[1 2] and the more important data are again reproduced (Fig. 6). The various intensities were measured with a specially constructed ionization chamber, made of goldbeater's skin and having a volume of 1 cubic centimeter. This chamber measures the radiation intensity independently of the wave lengths over the range used in Grenz-ray therapy. The curves were obtained with a Muller tube, the distance from the window to the chamber being 4 cm., that is, 9.6 cm. from the focus to the chamber. For the sake of comparison, in addition to the curves obtained with the Muller Grenz-ray tube at 4, 5, 6, 8, 10, and 12 K.V., an absorption curve is illustrated which is obtained by means of an ordinary Coolidge tube operated at 12 kilovolts. As we have stated, these curves hold only for the special tubes with which they have been measured; they may be quite different for other tubes. Furthermore, the quality distribution measured would be different if the measurements had been made at greater distances since the air would act as a filter and "harden" the Grenz-ray beams. We have previously discussed this effect and further extensive experimental data regarding it were recently presented by Meyer,[10] using filters of 0.01, 0.013, 0.018, 0.025, 0.031, and 0.035 mm. aluminum and a Siemens integral dosimeter with a Grenz-ray chamber. This author also called attention to the fact noticed by others[3 6 11] that, due to the filtering effect of the sputtered tungsten on the window of the tube, Grenz-ray tubes harden with use. For this reason, it is necessary to repeat dosage measurements on Grenz-ray tubes at least after every 100 hours of use.

It must be mentioned here that some authors believe that the half value layer method of indicating radiation quality for Grenz rays is not necessary, and that indirect factors indicating the quality are entirely sufficient. However, on this point opinions are divided and controversies have arisen.[12]

Berger,[13] who at first was against the use of the half value layer, has since constructed a practical little apparatus to measure it. The apparatus consists of an aluminum foil of 0.01 mm. thickness which can be rotated around its axis in a small cylinder, the latter

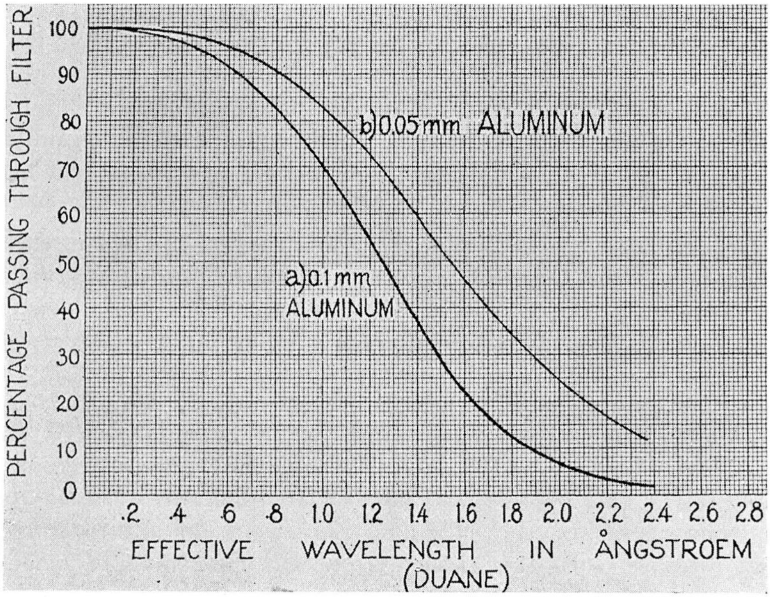

Fig. 7. Curves for the determination of the effective wave length for Grenz rays (Duane).

being placed between the Grenz-ray tube and the ionization chamber. The Grenz rays, which first pass through a small diaphragm, must penetrate different thicknesses of aluminum foil, depending upon the angle between the foil and the path of the rays. A pointer connected to the foil permits the reading of the angle on the outside of the apparatus on a scale which is directly calibrated in respective thicknesses. In our opinion, the determination of the half value layer is indispensable in Grenz-ray therapy.

Another method of indicating radiation quality is the effective wave length method suggested by Duane.[14] This has also been discussed previously and various data have been reported[1 2] on the effective wave lengths of Grenz-ray beams Fig. 7). We shall therefore, not go into this question again, especially since, in 1931, the International Standardization Committee at the Third International Congress of Radiology suggested that the roentgen-ray beams be characterized by the half value layer.

Absorption of Grenz Rays in the Human Skin

Formerly we presented half value layers for various layers of the human skin in combination with the half value layer in water and aluminum. The most important data in this connection are

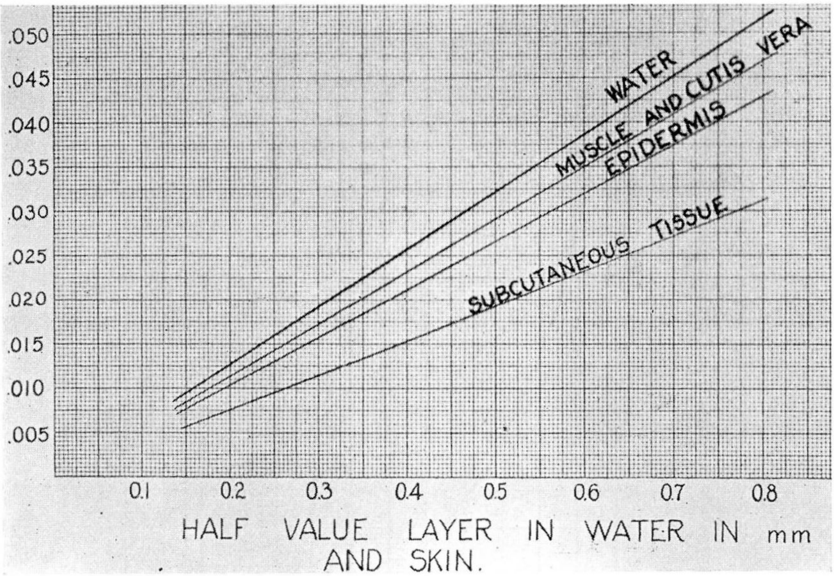

Fig. 8. Half value layer in aluminum as opposed to half value layer in water and various parts of the skin.

TABLE II

Half Value Layer in Aluminum as Compared with Half Value Layers in Water, Muscle, Cutis Vera, Epidermis, and Subcutaneous Tissue (in Millimeters)

Aluminum	Water	Muscle, cutis vera	Epidermis	Subsutaneous tissue
0.007	0.12	0.13	0.14	0.20
0.0125	0.20	0.22	0.24	0.33
0.0175	0.28	0.31	0.34	0.46
0.0250	0.39	0.43	0.47	0.64
0.0335	0.52	0.57	0.62	0.86
0.0400	0.62	0.68	0.74	1.02

contained in Table II, which gives an idea as to how far the Grenz rays of various half value layers penetrate into the skin (Fig. 8).

It is interesting to compare the absorption of the Grenz rays in skin with that of roentgen rays usually employed in dermatology. Only a very low percentage of roentgen rays produced at about 100 K.V. are absorbed by 1 mm. of skin, while over 50 per cent of Grenz rays produced at 10 K.V. are absorbed by 1 mm. of skin. This is illustrated in Fig. 9, taken from Bucky's book.[2]

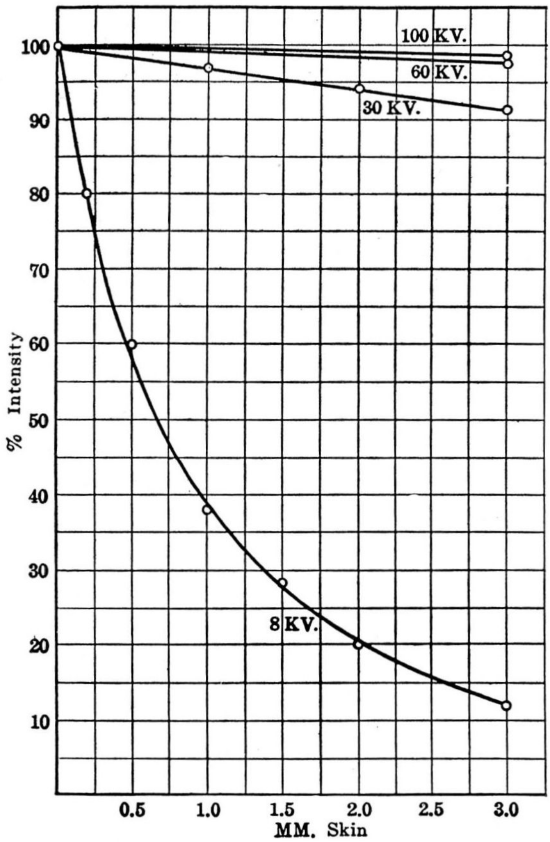

Fig. 9. Comparison of the absorption of Grenz rays and harder roentgen rays in the skin.

Determination of the Quantity of Grenz Rays

(*A*) *Indirect Method.* The indirect method of measuring the quantity of Grenz rays by means of the milliamperemeter has been found to be unsatisfactory. The intensity delivered by various tubes for the same number of milliamperes varies widely. The Grenz-ray apparatus also must be calibrated at various voltages for various milliamperages, since the secondary current changes if the voltage is changed. It is, therefore, advisable always to use the same milliamperage for a given voltage. It is still better, however, to measure the quantity of radiation by the direct method at the point of application.

(*B*) *Direct Method.* The quantity of Grenz rays is best determined by, and expressed in, the international roentgen unit,

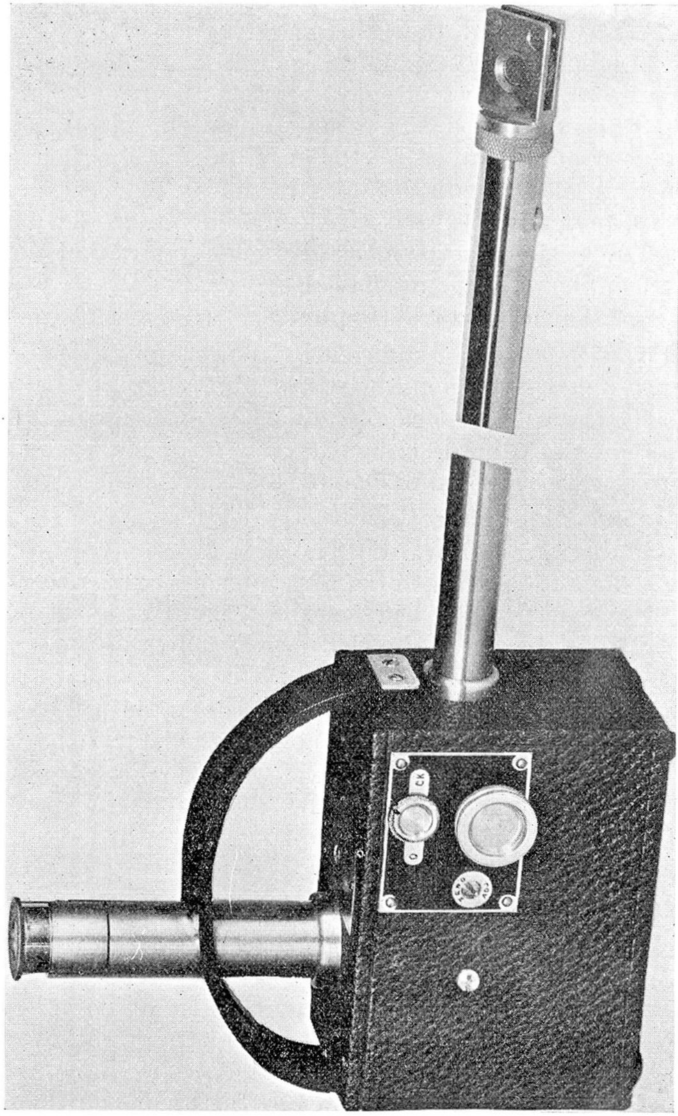

Fig. 10. Victoreen r meter with Grenz-ray chamber.

the definition of which, as well as the methods of determination, has been described frequently. A few years ago we modified our apparatus for the determination of the r unit in order to use it for the soft Grenz rays.[1] Since that time we have calibrated in roentgen units specially constructed dosimeters with small ionization chambers and our calibration compares favorably with that of others.

Originally we used 1 c.c. chambers built entirely of goldbeater's skin. However, we found that this construction was not stable enough for practical purposes and changed to a small metal ionization chamber with windows of goldbeater's skin (Fig. 10). It may be used in connection with any dosimeter; in the illustration, for instance, it is connected to a Victoreen r meter. This instrument has proven to be very practical and satisfactory for dose measurements with Grenz rays as well as with roentgen rays, since the intensity of Grenz rays may be measured at the point of application of the rays.* Similar instruments have been constructed by Kustner, in Gottingen, by Siemens, in Berlin, and by Strauss, in Vienna.

Since it was found to be sufficiently accurate on account of its independence of the wave lengths within the range of Grenz rays employed, all absorption measurements described above, and the dose measurements to be described later, were made by means of our calibrated goldbeater's skin chamber.

Photographic films have been suggested for dosage measurements in Grenz-ray therapy,[15] but the difficulties involved would seem to be too great to permit of accurate results. This observation is borne out by a controversy between the originators of the method and Reisner.[16] Another dosage method which we have used with good success is the photometer.[17] Packard[18] uses the death rate of *Drosophila* eggs to measure biologically the intensity of Grenz rays. Thaller[19] recently suggested a new method making use of a specially constructed photo-electric cell for the measurement of Grenz rays. In making these intensity measurements on Muller Grenz-ray tubes which have a ring-shaped focus, special precautions must be taken in order to avoid errors.[20]

Dose Measurements on Grenz Rays in Practical Use

In his latest papers, Bucky suggests the use of Grenz rays of half value layers of 0.015 to 0.03 mm. of aluminum and focal skin distances from 6 to 15 centimeters. In Table III we have collected a series of data on Grenz-ray qualities for various conditions from which it will be seen that the qualities suggested by Bucky were produced with our tubes at voltages of from 6 to 10 kilovolts.

Fig. 11 shows more data on Grenz-ray intensities for various focal distances and various voltages as published recently.[10] The data show that the intensity decreases rapidly with decreasing kilovoltage and increasing distances. We have stated previously[1,2] that it is difficult to fix erythema doses for Grenz rays and have

*Courtesy of the Victoreen Instrument Company, Cleveland, Ohio.

TABLE III

Half Value Layer in Millimeter Aluminum for Grenz Rays, Muller Tube, Chromium Iron Target, 10 Milliamperes

K.V.	4 cm. distance (window chamber), millimeter	20 cm. distance (window chamber), millimeter
4	0.007	......
5	0.0125	......
6	0.0175	0.0195
8	0.0250	0.0315
10	0.0335	0.0435
12	0.0400	0.0610

In Table IV are presented various Grenz-ray intensities in roentgen units.

TABLE IV

Radiation Intensities in R/Min. and Erythema Times per Dose of 250 r for Different Distances. Muller Tube, 10 Milliamperes

Distance in cm. (window chamber)	6 K.V. radiation		10 K.V. radiation	
	r/min.	Erythema time in minutes for 250 r	r/min.	Erythema time in minutes for 250 r
4	47.2	5.3	396.0	0.6
6	27.6	9.0	239.0	1.0
8	18.2	13.7	162.0	1.5
10	12.7	19.7	126.0	2.0
15	5.9	42.3	66.5	3.8
20	3.2	78.0	42.5	5.9

Radiation Intensities and Erythema Times per Dose of 250 r for Different Potentials. Muller Tube, 10 Milliamperes

E.m.f., K.V.	20 centimeters distance window chamber		4 centimeters distance window chamber	
	r/min.	Erythema time in minutes for 250 r	r/min.	Erythema time in minutes for 250 r
5	0.54	463.0	10.5	23.8
6	3.2	78.0	47.2	5.3
8	16.8	14.9	195.0	1.3
10	42.5	5.9	396.0	0.6
12	98.5	2.5	710.0	0.35

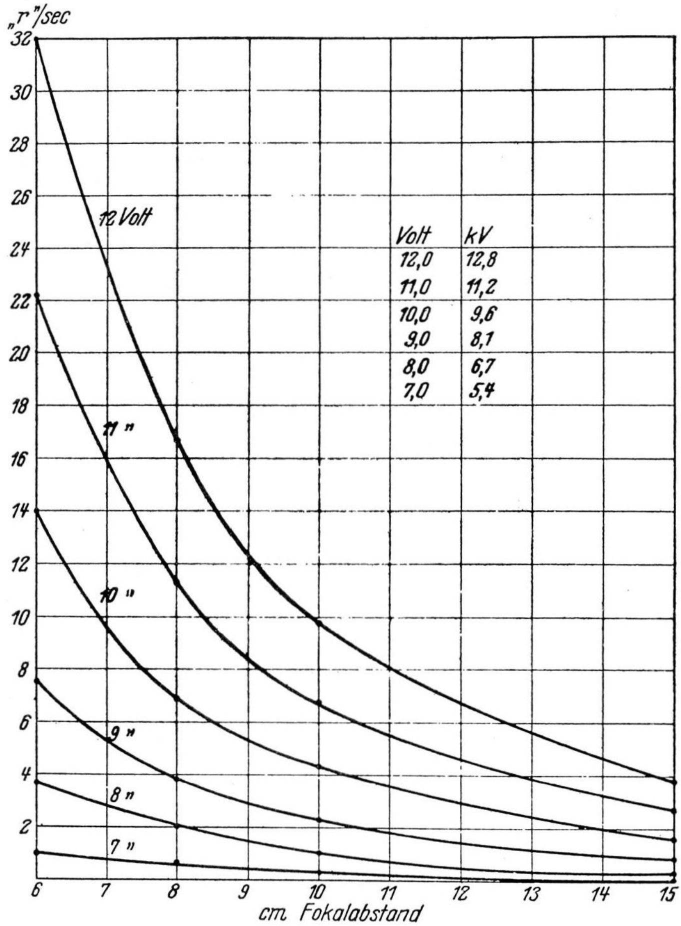

Fig. 11. Intensity of Grenz-ray beams produced at various voltages for various focal skin distances (Meyer).

made the suggestion that the value of 250 r units be accepted as a threshold erythema dose. Further experiments have shown that this value is approximately correct. Hausser and Schlecter[21] presented data on measurements of erythema doses with Grenz rays as compared to erythema doses produced with roentgen rays and have shown that the increase in the biologic reaction with increasing doses is much slower for Grenz rays than for X-rays (Fig. 12). Finally, attention must be called to the difficulty in radiating larger skin areas with the ordinary type tube, since at 4 cm. distance the diameter of the irradiated area is only about 4 centimeters, and there is a marked decrease in intensity in this area from the

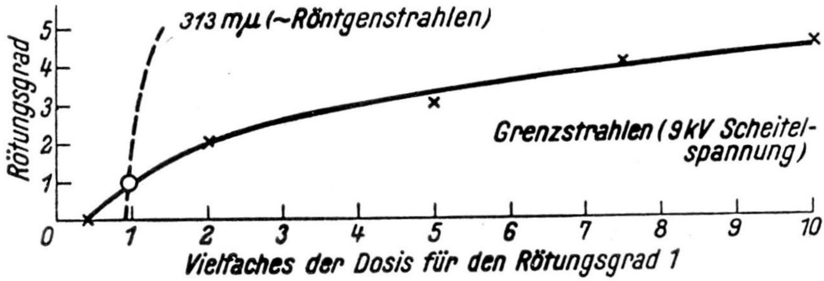

Fig. 12. Comparison of the degree of redness of the skin after application of increasing doses of roentgen rays and of Grenz rays (Hausser and Schlechter). Rotungsgrad: degree of erythema. Vielfaches der Dosis fur den Rotungsgrad I: multiple of the dose to produce one degree of erythema.

center toward the periphery. For practical treatments careful planning[22] of the combination of various areas has to precede the treatment: for a typical case this is illustrated in Fig. 13.

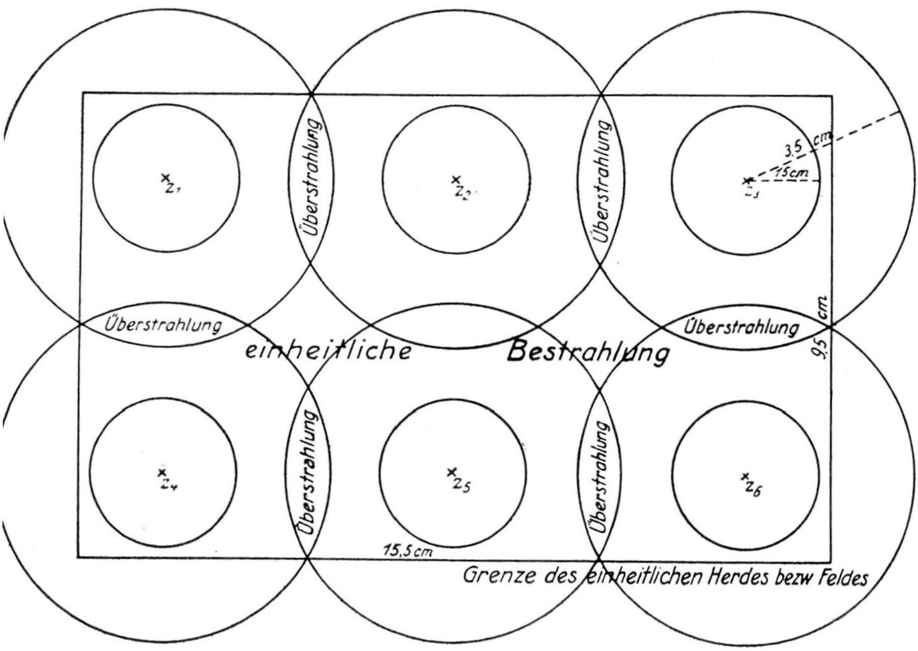

Fig. 13. Mapping out a large area of irradiation by combining various Grenz-ray beams.

Summary

Grenz rays are soft roentgen rays having a wave length of from 1 to 3 Angstrom units. They are produced in tubes with Lindemann glass or specially constructed windows of ordinary glass with voltages of from 6 to 10 kilovolts.

High tension apparatus and tubes for the production of Grenz rays are described.

Grenz rays are so soft that they are absorbed in the window of the tube and air to a considerable degree, therefore, only direct determinations of the radiation quality and quantity at the site of application are found to be satisfactory. These data should be accompanied preferably by an indication of the kilovoltage, the milliamperage, the type of tube, the target material, and the focal skin distance.

The absorption of Grenz rays in aluminum foil of 0.125 mm. thickness has been determined for different conditions of radiation and the half value layers of this radiation are found to be between 0.04 and 0.01 mm. of aluminum.

Data for translating half value layers of aluminum into half value layers of air, water, muscle, and various parts of the skin are given.

A small ionization chamber of goldbeater's skin, which is practical for dosage measurements in Grenz rays and is calibrated in roentgen units, is described. This chamber may be connected to any ionization dosimeter and the radiation intensity of Grenz rays may be measured independently of the wave lengths over the range used in Grenz-ray therapy. By means of this goldbeater's skin chamber the intensity of Grenz rays has been measured in r per minute for a number of radiation conditions, having been found to vary between about 400 r per minute and 0.5 r per minute.

The threshold erythema dose for Grenz rays is in the neighborhood of 250 r units. The increase of the physiologic effect of Grenz rays upon the skin with increasing dosages is much smaller than it is for roentgen rays.

References

1 Glasser, Otto, and Portmann, U. V.: The Physical and Clinical Foundations of Oversoft Roentgen-ray (Grenz Ray) Therapy. Am. Jour. Roentgenol. and Rad. Ther., 19:442-452, May, 1928.

2 Bucky, G.: Grenz-ray Therapy. With contributions by Otto Glasser and Olga Becker-Manheimer. The Macmillan Company, New York, 1929.

3 See the bibliographies in the following articles:
Wood, F. C., and MacKee, G. M.: Therapy with Long Wave Length X-rays (Grenz Rays). Jour. Am. Med. Assn., 96:111-115, Jan. 10, 1931, also "Radiology," 16:697-704, May, 1931.
Fuhs, H., and Konrad J.: Grenz-ray Skin Therapy. Urban and Schwarzenberg, Berlin, 1931.
Gabriel, G.: Indications and Results of Grenz-ray Therapy. Klin. Wchnschr., 9:2210-2213, Nov. 22, 1930.
Reisner, A.: Present-day Grenz-ray Therapy. Med. Klin., 26:597, April 17, 1930; also 26:637, April 25, 1930.
Bucky, G., Fuhs, H., Holthusen, H., Martenstein, H., Schreus, H. Th., and Spiethoff, B.: How can Grenz-ray Therapy Replace or Supplement the Present-day Radiotherapeutic Procedures in Dermatology? Dermat. Wchnschr., 2:1345, 1930.
Levy, D. M.: On Borderline Rays According to Bucky, Their Biological and Physical Properties, and Therapeutical Application. Acta Radiol., 11:204-216, 1930.
Fraticelli, A.: Observations on the Biological Action of Grenz Rays. Riv. di radiol. e fisica Med., 2:529-546, October, 1930.

4 Glasser, Otto, and Beasley, I. E.: An Improvement of Grenz-ray Tubes. Strahlentherapie, 40:389, 1930.

5 Frank, J.: On the Dosimetry of Grenz Rays, Fortschr. a. d. Geb. d. Rontgenstr., 36:1070-1080, November, 1927.

6 Rajewsky, B., and Gabriel, G.: Investigations on Very Soft Roentgen Rays (So-called Grenz Rays). Strahlentherapie, 30:308-333, 1928.

7 Kirsch, H.: Physical Investigations on Bucky's Grenz Rays. München. med. Wchnschr., 74:578, 1927.
Idem. Dosage of Bucky's Grenz Rays. München. med. Wchnschr., 75:603-605, April 6, 1928.

8 Klövekorn, G. H.: Dosage of Grenz Rays in r Units with the Eichstandgerät. Strahlentherapie, 29:190, 191, 1928.

9 Küstner, H.: Dosage of Bucky's Grenz Rays in r Units by Means of the Eichstandgerät. Strahlentherapie, 26:657, 1927; also 30:334-342, 1928.

10 Meyer, H. T.: On the Hardening of Grenz Rays by Air. Strahlentherapie, 38:778-784, 1930.

11 Warner, A. H.: Decrease in Efficiency of Grenz-ray Tubes. Radiology, 15:115, 116, July, 1930.

12 Gfrörer, O.: Uber die Eichung von Grenzstrahlröhren. Strahlentherapie, 36: 786-804, 1930.

Gfrörer, O., and Berger, Heinz: On the Necessity of Exact Dosage Prescriptions in Grenz-ray Therapy. Strahlentherapie, 38:184-186, 1930; also 40:590-598, 1931.

Fuhs, H., and Konrad, J.: On the General Treatment of Skin Diseases with Bucky's Grenz Rays. Strahlentherapie, 36:520-527, 1930; also 40:193-195, 1931.

13 Berger, H.: Facilitating Grenz-ray Therapy for the Practitioner by Means of a New Half Value Layer Meter. Dermat. Wchnschr., 92:492-495, April 4, 1931.

14 Duane, W., Hudson, J. C., and Sterling, H. N.: The Measurement of Effective Wave Lengths. Am. Jour. Roentgenol. and Rad. Ther., 20:241-245, September, 1928.

15 Görl and Voigt, L.: The Erythema Dose for Grenz Rays. Röntgenpraxis, 2:264-270, March 15, 1930.

16 Reisner, A.: The Erythema Dose for Grenz Rays. Röentgenpraxis, 2:566, 1930.

Görl and Voigt, L.: The Erythema Dose for Grenz Rays. Röntgenpraxis, 2:567, 1930.

17 Glasser, Otto, and Beasley, I. E.: The Dosimetry of Grenz Rays with the Wintz-Rump Photometer. Strahlentherapie, 28:611-614, 1928.

18 Packard, C.: The Relation of Wave Length to the Death Rate of *Drosophila* Eggs. Jour. Cancer Research, 13:87-96, March, 1929.

19 Thaller, R.: A New Measuring Device for Roentgen Rays, Especially Grenz Rays. Strahlentherapie, 41:332-335, 1931.

20 Boehmer, L.: On a Source of Error in Making Grenz-ray Measurements on the Muller Soft-ray Tube. Strahlentherapie, 38:353-357, 1930; also Dermat. Wchnschr, 2:1720, 1930.

21 Hausser, K. W., and Schlechter, E.: The Skin Erythema Dose as a Biologic Measure of the Biologic Effect of Radiation. Strahlentherapie, 27:348-352, 1927.

Idem: The Significance of the Wave Length in Radiation. Biology, 28:25, 1928.

22 Spiethoff, B., and Berger, H.: The Determination of the Areas in Grenz-ray Therapy. Strahlentherapie, 35:90-97, 1930.