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DOSAGE TABLES
FOR
RÖNTGEN THERAPY

OXFORD MEDICAL PUBLICATIONS

DOSAGE TABLES FOR RÖNTGEN THERAPY

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Translated from the
SECOND GERMAN EDITION

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PREFACE TO THE SECOND GERMAN EDITION

SEVEN years have elapsed since the first edition of my Dosage Tables appeared. During that time X-ray therapy has developed considerably, especially on the technical side. The apparatus and tubes have become more powerful, methods of measuring have been much improved, and the technique of irradiation has undergone many modifications. The form of the second edition, therefore, shows a radical change from that of the first: many of the sections are new, and many of the existing ones have had to be rewritten, but the general structure of the book has not been altered. Its object remains the same, namely to assist the practical radiologist to estimate dosage without the necessity for long measurements and repeated calculations. It is not a 'prescription book'; it is directed entirely towards the estimation of physical quantities. This estimation is necessary and will remain so, for whatever stress is laid upon biological factors it must always be remembered that the biological effect of X-rays can only be ascertained quantitatively by means of physical constants.

FRIEDRICH VOLTZ.

MUNICH, *April* 1928.

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I

INTRODUCTION

In the therapeutic use of X-rays a fundamental distinction must be drawn between (i) the *indications* for irradiation and (ii) the method of its application.

(i) The indications for X-rays constitute a purely medical problem. The question of whether to irradiate or not must always be decided by experimental and statistical evidence.

(ii) The application of X-rays is a biological and physical matter. The question of how to irradiate can only be decided after two other questions have been put and answered. These are:

a. What quantity of radiation is to be administered in a given case?

b. What conditions are necessary to produce this quantity?

The first question deals with the biological and the second with the physical aspect of the problem of dosage. It has already been mentioned in the preface that these dosage tables are not a handy prescription-book but a means of estimating physical quantities. The problem of the 'biological' dose will therefore only be considered in so far as it bears on that of the 'physical' dose, with which the succeeding chapters are mainly concerned.

II

GENERAL RULES

THE physical dose is governed by three basic physical factors, namely:

(i) spreading of the X-rays,
(ii) absorption of the rays,
(iii) scattering of the rays.

1. Spreading.

This depends upon the well-known law of inverse squares, i.e. that the intensity of the radiation falling on two unit areas placed at right angles to the beam, is inversely proportional to the square of the distances of those surfaces from the focus of the X-ray tube. If two spheres be imagined, of radius r_1 and r_2 respectively and having their common centre at the focus F of an anticathode A (Fig. 1), the rays given off from the anticathode will be distributed over those parts of the surfaces of the spheres O_1 and O_2 which are bounded by the plane mn. If the quantity of rays coming from the anticathode is denoted by 1, the intensity J, passing through the spherical area O_1, i.e. energy per square centimetre per second, is given by

$$J_1 = \frac{1}{O_1} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Similarly, the intensity passing through each square centimetre of O_2 is J_2.

$$J_2 = \frac{1}{O_2} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Now the areas of the hemispheres O_1 and O_2 are

$$O_1 = 2\pi r_1^2 \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and

$$O_2 = 2\pi r_2^2 \quad . \quad . \quad . \quad . \quad . \quad (4)$$

On substituting these values of O_1 and O_2 in (1) and (2) we obtain

$$J_1 = \frac{1}{2\pi r_1^2} \quad . \quad . \quad . \quad . \quad (5)$$

$$J_2 = \frac{1}{2\pi r_2^2} \quad . \quad . \quad . \quad . \quad (6)$$

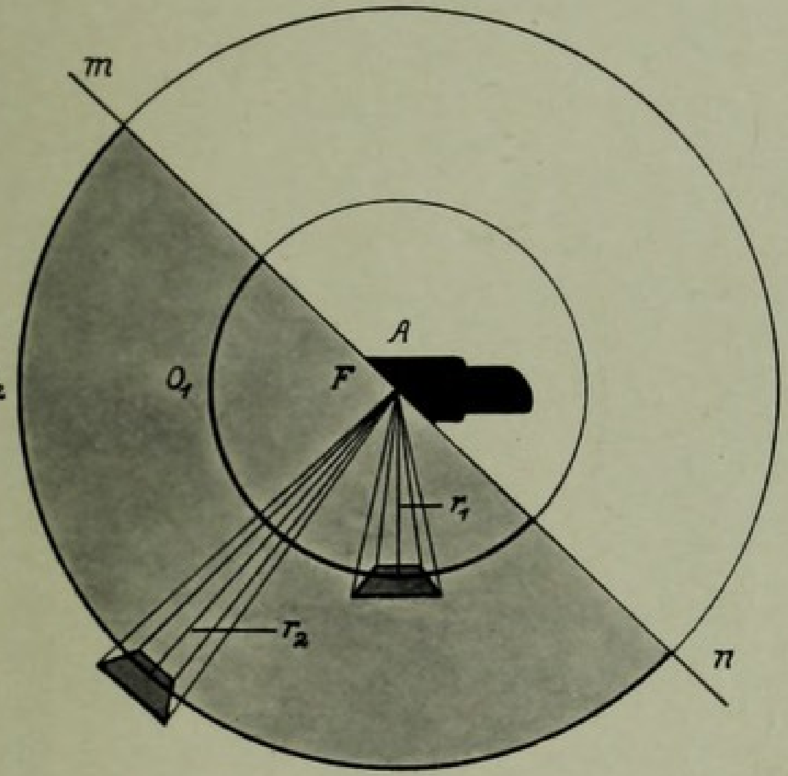

Fig. 1.

and by combining 5 and 6 we get the final equation:

$$J_1 : J_2 = \frac{1}{r_1^2} : \frac{1}{r_2^2} \quad . \quad . \quad . \quad . \quad (7)$$

$$\text{or } J_1 : J_2 = r_2^2 : r_1^2$$

The application of this fact of 'spreading' as expressed in (7), and known as the 'inverse square' law, enables the calculation of the intensity at a distance r_2 to be made, provided that the intensity at a given distance r_1 is known. Tables I–IX were calculated on this basis.

2. Absorption.

This depends upon the following factors:

When X-rays pass through a body the absorption in that body is increased in the following ways.

a. By increasing the wave-length of the rays, and so reducing their penetrating power; provided that no change occurs in the dimensions of the body or in its chemical composition.

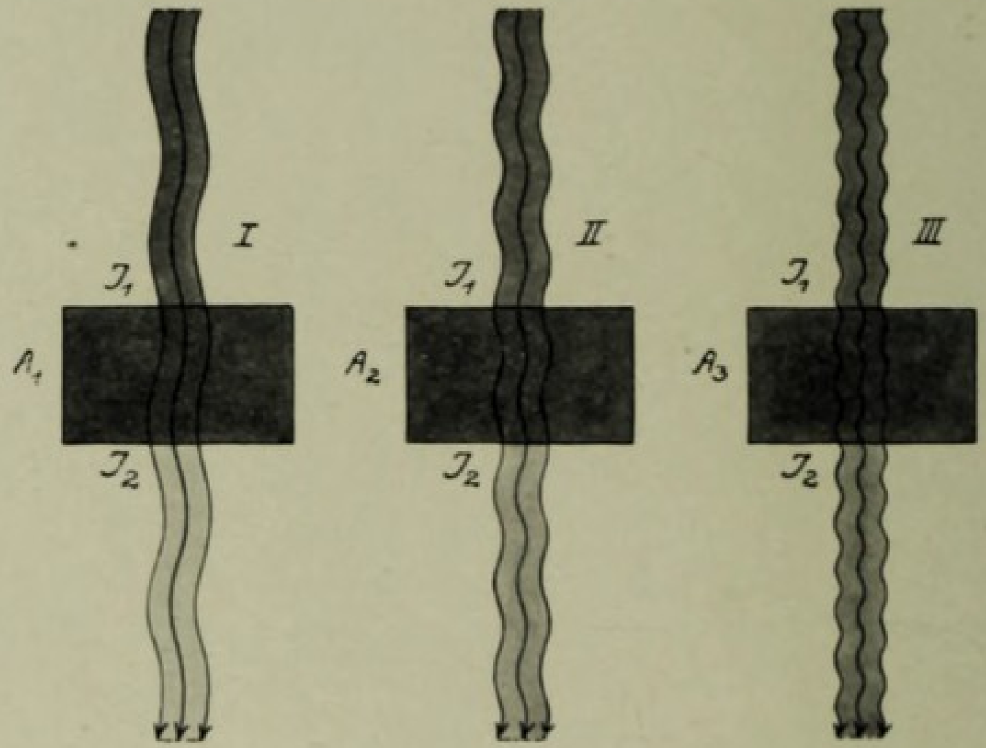

Fig. 2.

b. By increasing the thickness (depth) of the body; provided that the concentration of the rays and the chemical composition of the body remain unchanged.

c. The higher the atomic weights of the chemical elements which constitute the body, the greater the absorption; provided the dimensions of the body and the quality of the radiation remain constant.

Illustrations of these three points will now be given:

a. Diagrams I, II, and III in Fig. 2 represent three radiations of different quality, the respective penetrating powers of which are soft, medium, and hard. Let these three beams fall on three identical absorbers, A_1, A_2, and A_3, from the same distance and through the same aperture; then the energy of the beam remaining in the absorbers is greatest in A_1, less in A_2, and least in A_3. The loss due to absorption can be measured

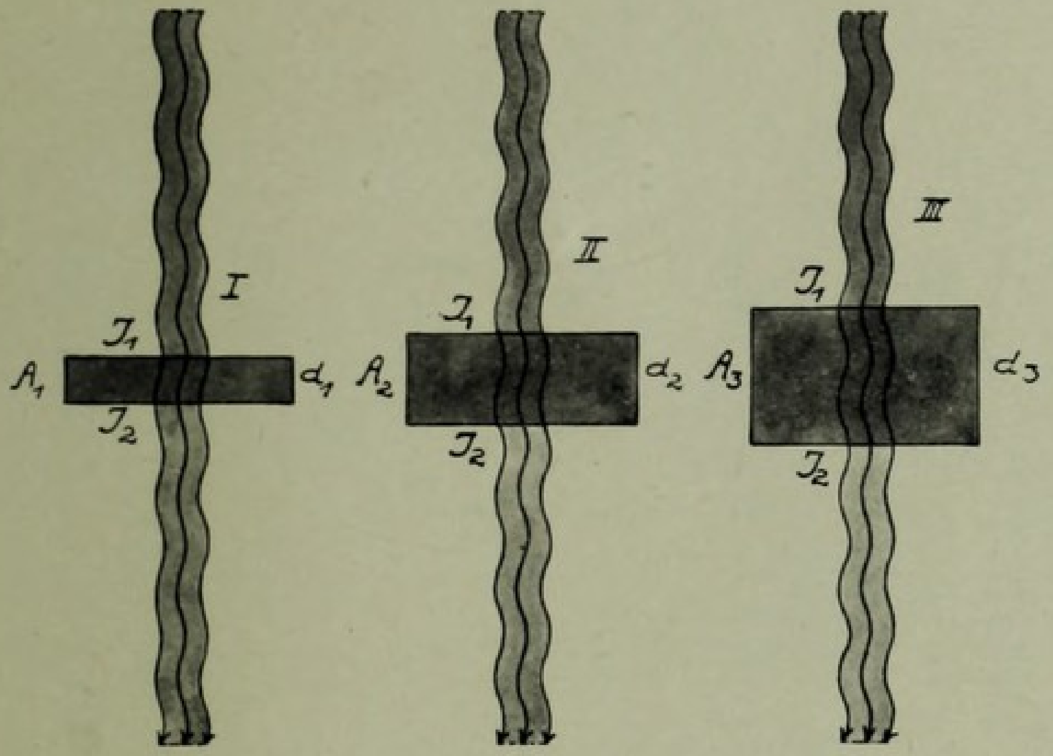

Fig. 3.

by determining J_1 and J_2, the intensity before and after passing through the body. In the present example

$$(J_1-J_2)_{A_1} > (J_1-J_2)_{A_2} > (J_1-J_2)_{A_3} \qquad (8)$$

b. In Fig. 3, A_1, A_2, and A_3 are three absorbent bodies, the thickness of which is respectively d_1, d_2, and d_3 cm. A_1 will therefore absorb less radiation than A_2, and A_2 less than A_3. (It is assumed that the composition of the rays, the size of the beam, and the distance are all constant.) If J_1 and J_2 are estimated, then

$$(J_1-J_2)_{A_1} < (J_1-J_2)_{A_2} < (J_1-J_2)_{A_3} \qquad (9)$$

c. If we consider three absorbers of identical dimensions but made of aluminium (atomic weight 27), sulphur (atomic weight 32), and iron (atomic weight 56), shown in Fig. 4 at A_1, A_2, and A_3 respectively, and if we assume the same composition of the rays, then A_1 will absorb less than A_2, and A_2 less than A_3. If J_1 and J_2 are measured in these cases we have

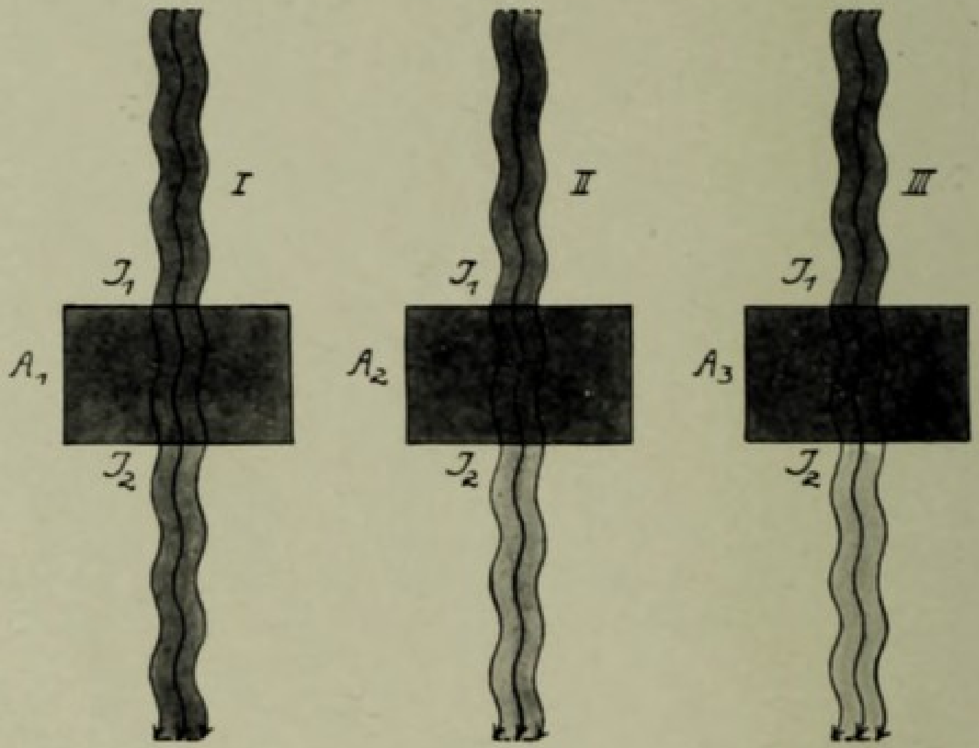

Fig. 4.

$$(J_1-J_2)_{A_1} < (J_1-J_2)_{A_2} < (J_1-J_2)_{A_3} . \qquad (10)$$

The increase in absorption is regular; it follows the order of the chemical elements in the table of atomic weights.

3. Scattering.

If a beam of X-rays traverse a body, a part of the rays is scattered; the actual amount of scattering depends on the volume of the body.

Scattering of X-rays is of the greatest importance in X-ray therapy. It plays the more important role, the shorter the wave-length of the radiation and the smaller the atomic number of the scattering substance; which are just the conditions in the case of deep X-ray therapy.[1]

If we consider a body *A*, Fig. 5, irradiated by a beam of X-rays, *R*, every element of volume which absorbs energy from the beam scatters it in all directions to a greater or less degree,

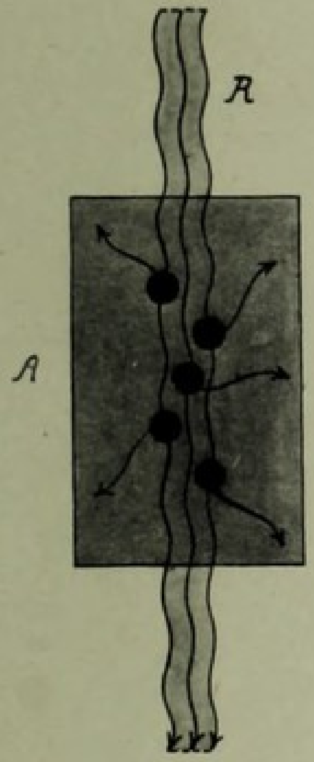

Fig. 5.

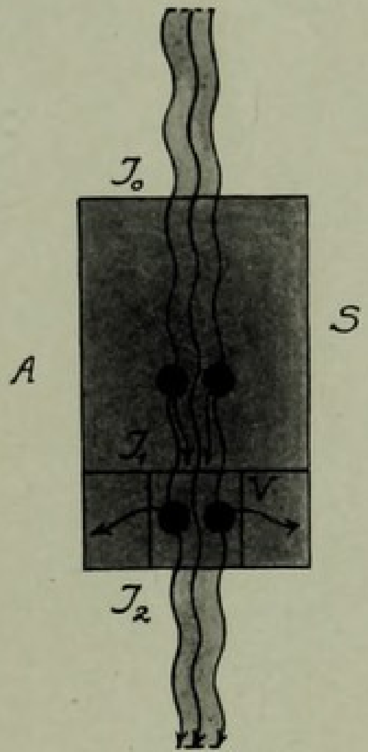

Fig. 6.

e.g. the greater the dimensions of the irradiated space, the more elements of volume will lie in the beam, and consequently the more scattered radiation will be given out.

The practical significance of this will be seen in Fig. 6.

Let *A* be an absorber, of which we will consider *V* to be a portion which will absorb a definite quantity of radiation. If absorption is the only process in the stratum *S*, which is above the portion *V* considered, the quantity of radiation energy in *V* will be that due to the absorption loss in that part, i.e. $J_1 - J_2$.

---

[1] The scattering under these conditions is small, but this constitutes the main secondary action.

If, however, as actually occurs, scattering as well as absorption takes place in the stratum *S*, some of the scattered radiation from *S* will enter *V*, and must be taken into account as an addition to the ordinary supply to *V*. At the same time, however, *V* is itself scattering a certain amount of energy, and some of this amount will pass out of *V*. The additional radiation entering the space *V* is the more enhanced, the greater the scattering in the overlying stratum *S*, and, when other factors are constant, this depends on the dimensions of the X-ray beam, as may be seen in Fig. 7.

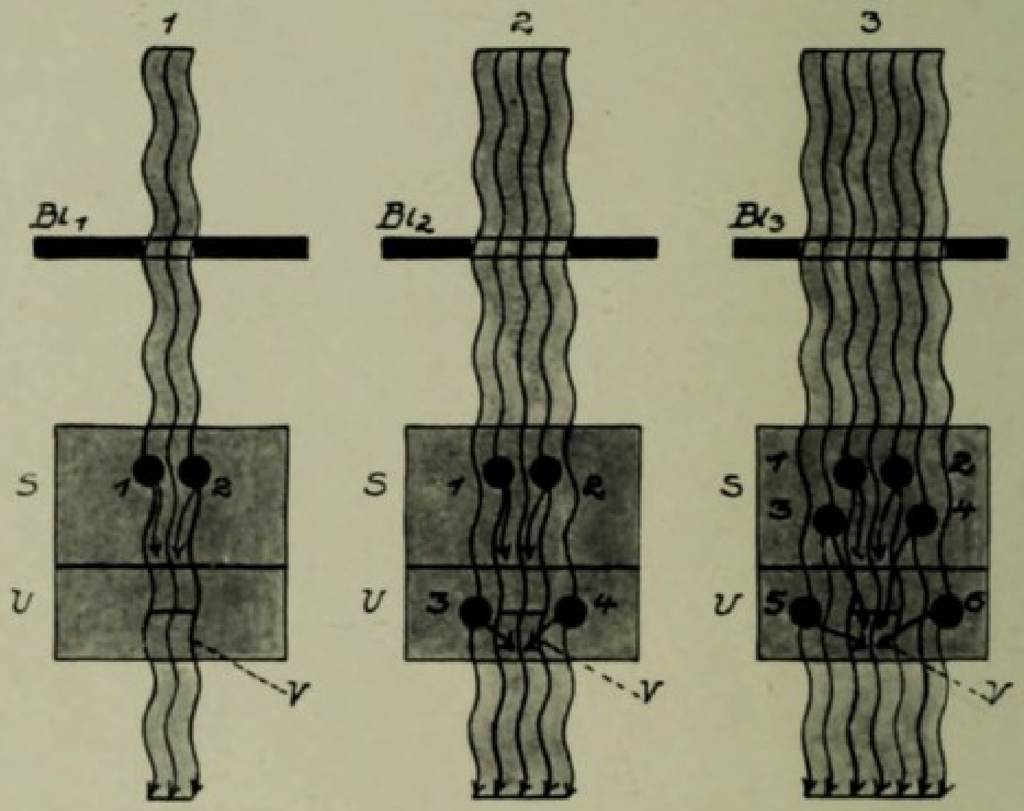

Fig. 7.

Fig. 7 (1) shows a beam of rays which is restricted by its passage through a diaphragm Bl_1 to such an extent that it can only traverse the element *V* of the body. In addition to this, *V* only receives from the overlying stratum *S* an extra amount of radiation which is represented between the two arrows 1 and 2. If the aperture is increased to a diameter Bl_2, as in

Fig. 7 (2), the bundle penetrating the absorbent body will be of such a size that it will irradiate, as well as the element V, a stratum U surrounding it. Scattering will also take place in this stratum, and the scattered radiations are represented by arrows 3 and 4. It will be seen that V in Fig. 7 (2) receives a considerably larger quantity of scattered radiation. The amount of energy absorbed by V is greater in Fig. 7 (2) than in Fig. 7 (1). If the aperture be still further enlarged to Bl_3, as in Fig. 7 (3), the irradiated area will be still greater. The additional radiation reaching V is still further increased, and is shown by the arrows 1, 2, 3, 4, 5, and 6. The energy absorbed by V will consequently undergo a further increase. If D_1, D_2, and D_3 represent the respective amounts of energy absorbed by V in each of these three instances, then

$$D_1 < D_2 < D_3 \quad . \quad . \quad . \quad . \quad (11)$$

These values cannot be calculated, because of the accessory factors involved, but must be ascertained for each case by suitable tests. Tables XIII–XVI inclusive show the increase in the amount of radiation absorbed owing to a given increase in the aperture of the diaphragm under normal working conditions.

III

SPECIAL FACTORS

In practical X-ray therapy there are seven special concepts which need to be particularly considered and with which the practitioner must be familiar. They are:

1. The physical dose.
2. The biological dose.
3. The dosage quotient.
4. The percentage deep dose.
5. The effective dose.
6. The practical dose.
7. The absolute unit of dosage.

1. The Physical Dose.

a. Fundamental Axiom.

The magnitude of the biological effect on a given tissue depends upon the amount of radiation energy absorbed by that tissue. This 'physical dose' is therefore extremely important to the physician. This axiom was introduced into dosimetry by Christen. Its bearing on the dose is expressed by the following law:

The physical dose is determined by the intensity and penetrating power of the radiation. It stands in direct proportion to the intensity, and in indirect proportion to the penetrating power.

Fig. 8 shows a body A penetrated by a beam of rays R. The energy at the surface of entry is E_1, and at the surface of exit, after the body has been traversed, it is E_2. The difference $E_1 - E_2$ represents the energy absorbed by the body, it is therefore known as the *physical dose* received by the body A. The unit of physical dosage is defined as the radiant energy absorbed per unit-volume of the medium. If V be the volume of that part of A which is traversed by the rays, and D the average dose throughout that part, then

$$D = \frac{E_1 - E_2}{V} \quad . \quad . \quad . \quad . \quad (12)$$

The dose determined by this equation is, however, only a mean. The uppermost stratum S_1 will receive a larger dose than the lowest stratum S_n, for energy is lost by absorption in the strata S_2, S_3, S_4 . . . S_{n-1} which lie above it, and S_n will therefore receive less than any of the others. Since this is always the case in practical X-ray therapy, the concept of the mean dose is not adequate for practical purposes, where it is more important to determine the dose at a given point in the irradiated tissues.

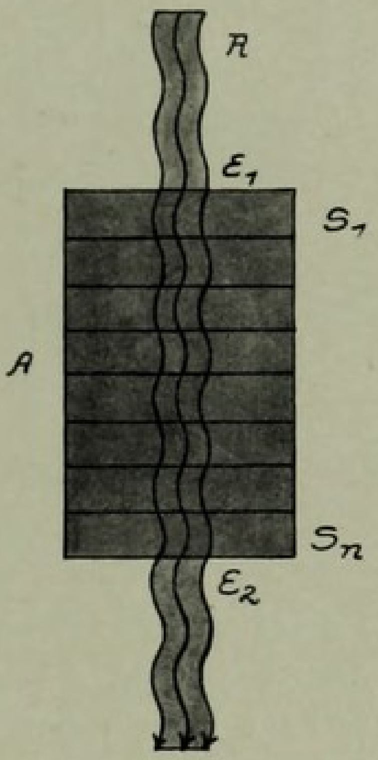

Fig. 8.

The exact definition of the dose is therefore as follows:

The *dose* is that amount of radiant energy which is absorbed during the period of irradiation by an infinitesimally small element of the body A, divided by the volume of that element.

Apart from the dose received during the whole period of irradiation, it is important, for therapeutic reasons, to know the dose administered during a unit of time. To meet this need Grossmann introduced the concept of the 'unit-time dose', the definition of which is as follows:

The *unit-time dose* is that amount of radiation absorbed in one second by a small volume element of the body A, divided by the volume of the element.

If the composition and amount of the beam are unchanged, the dose reaching an element of the irradiated body is equal to the unit-time multiplied by the time of irradiation in seconds.

In the practical application of these ideas it is necessary to make a further distinction between the *surface* dose and the *deep* dose.

The *surface dose* is that amount of radiation absorbed during the whole period of exposure by an infinitesimal spatial element on the surface of the irradiated body, divided by the volume of the element.

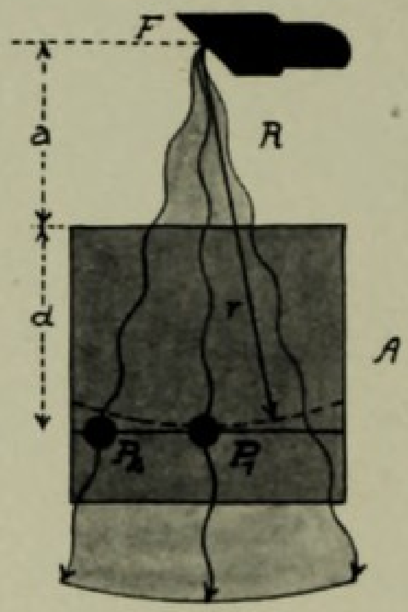

Fig. 9.

The *deep dose* is that amount of radiation absorbed during the whole period of exposure by an infinitesimal spatial element in the depths of the irradiated body, divided by the volume of the element.

b. The space distribution of the dose.

The biological effect exerted upon an irradiated body depends upon the size of the dose. Since the distribution of the rays in the body is not uniform, it is absolutely necessary, if the biological effect is to be ascertained, to know the manner of their distribution throughout the irradiated space. For the experimental determination of the distribution use is made of 'phantoms'. These may be of paraffin-wax, which only measures limited amounts, or of water, with which amounts of any size can be measured.

The distribution of the dose throughout the space depends upon the three factors referred to earlier:

(i) spreading,
(ii) absorption,
(iii) scattering.

(i) *Spreading*. Fig. 9 represents a body *A* irradiated by a beam *R*. The point P_1, at a depth *d* in the body, receives a larger amount of radiation than the point P_2 at the same depth, because the distance from the focus *F* of the tube is greater at the point P_2 than at the point P_1, which is situated at the centre of the beam. The smaller the distance from the focus A the greater will be the difference between the radiation received at P_1 and P_2 respectively.

(ii) *Absorption.* In Fig. 10, A is a body traversed by a beam of rays R. The point P_1 at the surface of the body receives a larger amount of radiation than the point P_2 at a depth d in the body, for, apart from the expansion of the beam, which makes the concentration at P_2 less than that at P_1, absorption takes place in the stratum d.

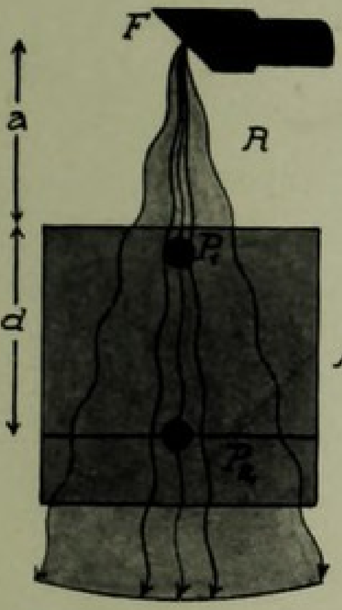

Fig. 10.

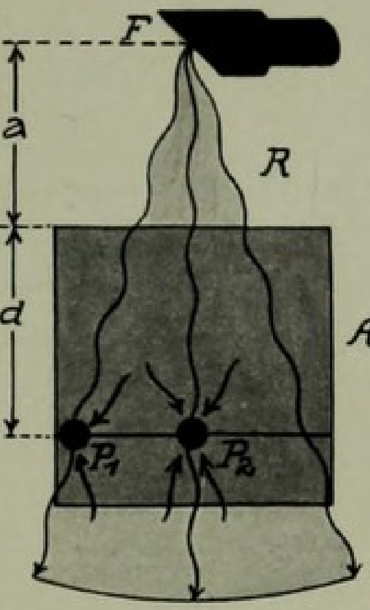

Fig. 11.

(iii) *Scattering.* In Fig. 11, A is a body traversed by a bundle R. The point P_2 at a depth d in the body receives rays scattered from all parts, while the point P_1 at the edge of the beam only receives rays scattered from the space traversed by it.

From these various factors which govern the space distribution of the dose, it follows that the values laid down in the following tables for the *practical dose* hold good only for the centre of the bundle.

As Holfelder's experiments demonstrated, the points within the beam at which the dose is equal are practically equidistant from the focus. In any section of the beam the dose is almost constant over a large area and only diminishes near the edge, so that the values given in the tables may be taken as accurate for these areas. It is only necessary to consider the marginal diminution caused by the spreading of the rays when working with very small focal distances; a practical example will show that this may be easily done with the help of the tables. The tables have been made from measurements on 'phantoms'; it is necessary to remember, when using them in practice, that errors may occur if the irradiated region contains air-spaces or gas-bubbles, because absorption and scattering in air and gas is much less than in tissue.

2. The Biological Dose.

a. General principles.

The biological dose is equal to the physical dose multiplied by the coefficient of sensitivity of the irradiated tissue. It is therefore governed by the sensitiveness of the tissue to X-rays. If D' is the biological dose and D the physical dose, the coefficient of sensitivity is expressed by the following equation:

$$\sigma = \frac{D'}{D} \quad . \quad . \quad . \quad . \quad (13)$$

By the sensitivity of a tissue to X-rays we understand that specific quality of a living system which allows the radiant energy to induce in it either increased anabolism or increased katabolism, according to the effect which the rays happen to exert. The concept of sensitivity is always a relative one and depends on the condition of the system; it is used with reference to the sensitivity of a systemic entity. That systems differ in sensitivity may be explained by reference to their energy-functions.

In this connexion it is also necessary to consider the familiar and much-discussed law of Bergonié and Tribondeau, which states:

A cell is sensitive to X-rays in proportion

1. to its reproductive powers;
2. to the stage of its mitosis:

and in inverse proportion

3. to the extent to which its morphology and functions—apart from reproduction—have become definitely fixed.

This law, stated in terms of energy, is as follows:

1. The greater the working capacity of a cell due to its metabolism, the more sensitive is it to X-rays.
2. The greater the amount of energy used up by a cell in the process of division, the more sensitive is it to X-rays.
3. The less definitely-fixed is the energy of the cell and the more work it must perform to attain to its definitive condition, the more sensitive is it to X-rays.

This energic view of X-ray sensitivity is justified by the fact that the biological effect of X-rays is ultimately referable to the energy-changes which they bring about. If their effect be regarded purely in terms of energy, it follows that the changes they cause can only be due to those radiations which are absorbed within the irradiated body. This does not, of course, mean that the radiation energy which is absorbed in the body can be assumed to be the same as the amount of energy realized in the body as a result of the biological changes. The visible biological changes come to a standstill a certain time after the irradiation, and Grossmann was correct in stating that it is possible to resolve the biological processes which take place under the influence of irradiation into two consecutive phases, consisting of

(i) those changes which take place immediately in the irradiated tissues under the influence of the radiation energy absorbed; this leads to changes in the cellular composition and in that of the blood and lymph exposed to the rays.

(ii) those biological changes which occur as a result of the first phase, and which may continue for hours, days, or even weeks.

The former of these two phases is purely physico-chemical, and its magnitude depends entirely upon that of the physical dose. The latter phase is purely biological and depends, when the physical dose is constant, upon the sensitivity of the irradiated tissues.

b. Sensitivity Scales.

The investigations of H. E. Schmidt, Mitscherlich, Beclère, Wetterer, Krönig and Friedrich, Seitz and Wintz, and others have established certain definite data for the construction of scales of sensitivity for tissues of various kinds. The following Scale 1 gives a survey of the differences that exist. The sensitivity of the skin of an adult is taken as normal and allotted the basic value of $\sigma = 1$. The numbers in Scale 1 indicate the factor by which the sensitivity of other tissues is greater or less than that of adult skin. On the basis of this difference in sensitivity, Seitz and Wintz have constructed their system of 'biological measurement', taking the sensitivity of the skin as unity. The unit dose for this system, called the 'unit skin dose', is of course one which the skin will tolerate. Seitz and Wintz defined as a unit skin dose (H.E.D., Hauteinheitsdosis) that quantity of radiation which would cause a slight erythema after eight days and a slight browning after four weeks.

Starting from this principle of a unit skin dose, to which they give the value of 100%, Seitz and Wintz have worked out a series of other doses, which are set out in Scale 2.

It should be noted in using this system of measurement that, whereas the unit skin dose is not a lethal one, all the others are to be classed as lethal. The system has been much criticized during recent years, and the doses laid down for treating sarcoma and carcinoma and as stimulating carcinoma have been the object of especial attack. Although it must be admitted

SCALE 1

	Sensitivity σ as measured by Seitz and Wintz and by Krönig and Friedrich.	*Sensitivity σ as measured by Beclère and Wetterer.*
Adult bony tissue		$\sigma=0{\cdot}02$
Adult cartilaginous tissue		$\sigma=0{\cdot}05$
Muscular tissue	$\sigma=0{\cdot}8$	$\sigma=0{\cdot}1–0{\cdot}3$
Connective tissue		$\sigma=0{\cdot}2–0{\cdot}4$
Adult skin	$\sigma=1{\cdot}0$	$\sigma=1{\cdot}0$
Intestine	$\sigma=1{\cdot}1$	
Adult facial skin, liver, kidneys, and blood-vessels		$\sigma=1{\cdot}4$
Carcinoma cells	$\sigma=1{\cdot}5–1{\cdot}1$	
Mucosae, hair roots, child's skin		$\sigma=2{\cdot}0$
Sarcoma cells	$\sigma=2{\cdot}5–2{\cdot}1$	
Cartilage of child		$\sigma=2{\cdot}8$
Facial skin of child		$\sigma=3{\cdot}0$
Tuberculous tissue	$\sigma=3{\cdot}0$	
Testicles, ovaries, spleen, bone-marrow	$\sigma=3{\cdot}5$	$\sigma=3{\cdot}7$
White blood corpuscles		$\sigma=4{\cdot}0$

SCALE 2

	%
Unit skin dose	100
Castration dose	35
Sarcoma dose	60–70
Carcinoma dose	90–110
Dose stimulating carcinoma	35–40
Intestinal dose	135
Muscle dose	180
Tuberculosis dose	40

nowadays that carcinoma has no uniform sensitivity-quotient—as investigations on the abundant material at our clinic have shown—it is nevertheless true that the Seitz and Wintz dose of 90–110% is an optimum for carcinoma and should be adhered to in treatment. Quite recently Opitz has expressed the opinion that the problem of the retrogression of carcinoma under X-rays is entirely a biological one. Purely biological processes certainly play a very substantial part, but it should always be remembered that they are primarily set on foot by the radiation-energy, which is a physical factor.

Scale 3 shows the doses of Scale 2 in terms of the notation of Krönig and Friedrich, in which the unit skin dose of Seitz and Wintz is given the value of 170 'e'. Friedrich's 'e' unit, together with the R. unit, will be discussed more fully later on.

SCALE 3

Unit skin dose	170 *e*
Castration dose	58 *e*
Sarcoma dose	102–119 *e*
Carcinoma dose	170–187 *e*
Intestinal dose	220 *e*
Muscle dose	306 *e*
Tuberculosis dose	70 *e*

By using the sensitivity-scale set out in Scale 1 the scope of the biological system of Seitz and Wintz can be enlarged at will and translated directly into 'e' notation.

3. The Dosage Quotient.

The dosage quotient is obtained by dividing the surface dose D_0 by the deep dose D_1. It must be emphasized that in deep X-ray therapy the dosage quotient should be as small as possible.

In Fig. 12 S_1 is a stratum within an absorbent body A. D_1 is the dose received by an infinitesimal spatial element 2 in this stratum, and D_0 is the dose received by an infinitesimal spatial element 1 at the surface of the body *A*. The dosage quotient is $\frac{D_0}{D_1}$. Its size is governed by the three familiar factors:

(i) spreading,
(ii) absorption in the overlying stratum h,
(iii) scattering.

(i) If the overlying stratum h and the quality of the radiation are constant, the dosage quotient $\frac{D_0}{D_1}$ will be the smaller—and more suitable—the greater the distance of the source of the rays from the body *A*, since the difference in the thickness of the beam at the surface and in the interior will be proportionately less.

(ii) Given a constant overlying stratum h and a constant focal distance, the dosage quotient $\frac{D_0}{D_1}$ will be smaller, and so better, the less the absorption that takes place in the overlying stratum h and the greater the penetrating power of the rays.

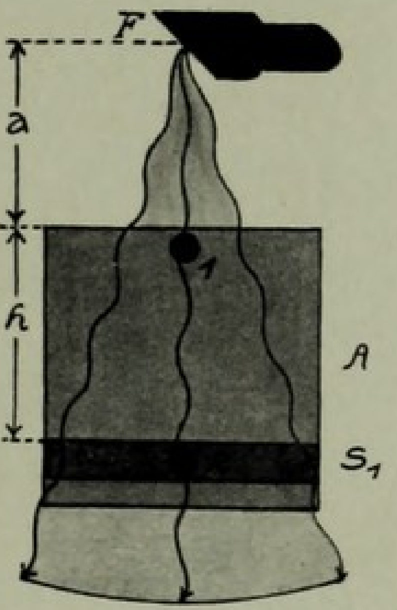

Fig. 12.

(iii) If the overlying stratum h, the focal distance, and the quality of the radiation remain the same, the dosage quotient $\frac{D_0}{D_1}$ will improve in proportion to the scattering of the rays in the body, a factor which increases with the size of the beam.

To obtain an optimum dosage quotient, therefore, these three conditions are necessary:

a. The lengthening of the focal distance.

b. The improvement of the quality of the rays by choice of the most suitable filters, and *c*. The increase of the size of the bundle by enlarging the field of incidence.

4. The Percentage Deep Dose.[1]

The percentage deep dose is the deep dose divided by the superficial dose: $\frac{D_1}{D_0}$, with a focal distance of 23 cm. from the skin, an overlying stratum of 10 cm. and a field of incidence of 6 × 8 cm. It is the reciprocal of the dosage quotient in a particular case, and in deep X-ray therapy should be as large as possible.

The concept of the percentage deep dose, introduced by Wintz, is chiefly understood as an expression of quality, and will be used exclusively with this significance in the present tables, and represented by the initials P.D.D. It is measured with a focal distance of 23 cm. and an incidence-field of 6 × 8 cm., and denotes the quantity of radiation that remains after penetrating a layer of water 10 cm. thick or a body with an equivalent power of absorption, expressed as a percentage of the radiation present at the surface, i.e. at 23 cm. focal distance.

It is represented by the equation:

$$\text{P.D.D.} = \frac{D_1}{D_0} \quad . \quad . \quad . \quad . \quad . \quad (14)$$

If $D_0 = 100\%$, P.D.D. $= n\%$ of D_0.

The greater the penetrating power of the rays, the greater is the percentage deep dose.

5. The Effective Dose.

The effective dose is the deep dose divided by the surface dose, or $\frac{D_1}{D_0}$, with a focal distance of 23 cm. from the skin, an optional field of incidence, and a depth of 10 cm. The effective

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[1] Die prozentuale Tiefendosis.

dose is the reciprocal of the dosage quotient in a particular case.

If the distance from skin to burner be 23 cm., the amount of rays reaching a depth of 10 cm. varies with the field of incidence. When this is smaller than 6 × 8 cm. the dose D_1 will be smaller, and when it is larger than 6 × 8 cm. the dose D_1 will be greater, provided that all other factors remain constant. The reason for this is to be found, as we have seen, in the variation in the conditions of scattering.

In these tables the effective dose, or E.D., is that which is measured at a depth of 10 cm. and a focal distance from the surface of 23 cm. with a varying field of incidence. Like the percentage deep dose, or P.D.D., it is expressed as a percentage of the quantity of rays present at the surface, i.e. 23 cm. focal surface distance.

$$\text{E.D.} = \frac{D_1}{D_0} \quad . \quad . \quad . \quad . \quad . \quad (15)$$

If, therefore, D_0 be reckoned as 100%, the E.D. will equal m% of D_0. In the tables the effective dose is the basis for the calculation of the practical effective dose. With a focal distance of 23 cm. from the surface and a field of incidence of 6 × 8 cm., the effective dose, or E.D., is equal to the percentage deep dose, or P.D.D. For improving the effective dose the most important consideration is the enlargement of the field of incidence.

6. The Practical Dose.

The practical dose is the deep dose divided by the surface dose $\frac{D_1}{D_0}$, when the focal distance from the surface, the depth, and the field of incidence are all optional. The practical dose is equal to the reciprocal of the dosage quotient in each individual case. It must therefore be emphasized that in deep X-ray treatment the practical dose should be as large as possible.

The dose received by an irradiated space at a given depth does not depend upon the size of the incidence-field alone, but also upon the distance of the focus from the surface. The practical dose, or P.D., may be defined as that dose which is delivered when the depth, field of incidence, focal distance, and quality of radiation are all optional. It is the effective physical dose.

The practical dose, P.D., like the percentage deep dose, P.D.D., or the effective dose, E.D., is expressed as a percentage of the quantity of radiation present at the surface at the given focal distance:

$$\text{P.D.} = \frac{D_1}{D_0}. \qquad . \quad . \quad . \quad . \quad (16)$$

If $D_0 = 100\%$, the P.D. will be $x\%$ of D_0. When the focal distance from the surface is 23 cm. and the depth is 10 cm., the practical dose, P.D., and the effective dose, E.D., are the same. When the focal distance from the surface is 23 cm. and the field of incidence is 6 × 8 cm., the practical dose, P.D., at a depth of 10 cm. is the same as the percentage deep dose, P.D.D. The size of the practical dose, P.D., is determined by the same three factors as the dosage quotient:

i. spreading,
ii. absorption,
iii. scattering.

(i) The practical dose, P.D., given a constant overlying stratum and a constant quality of radiations, will be larger and, hence, better the greater the distance of the source of the rays from the absorbent body, for the difference between their density at the surface and at the given depth will be accordingly reduced.

(ii) The practical dose, P.D., given a constant overlying stratum and a constant focal distance from the surface, will be larger the less the absorption in the overlying stratum; that is, the greater the penetrating power of the rays.

(iii) The practical dose, P.D., given a constant overlying stratum, a constant focal distance from the skin, and a constant quality of radiations, will be the better the greater the scattering of rays throughout the body; that is, the greater the size of the beams.

The three conditions for improving the practical dose, like the dosage quotient, are therefore as follows:

a. The lengthening of the focal distance.
b. The improvement of the quality of the rays by choice of the most suitable filters, and
c. The increase of the size of the beam by enlarging the field of incidence.

7. The Absolute Unit of Dosage.

For a number of years movements have been in progress to fix an absolute standard of X-ray dosage, which shall on the one hand be capable of reproduction, and on the other shall provide a solid foundation for exact work and a means of comparing the work of different clinics and institutes.

Friedrich laid down as a unit of dosage that amount of radiant energy which produces ionization in air to such an extent that, when under conditions of saturation, each cubic centimetre transports one electrostatic unit of quantity; which is the quantity of electricity which, when applied to a conductor of unit capacity (1 cm.), raises its potential by an electrostatic unit (300 volts). This unit is Friedrich's unit 'e'. The Standardization Commission of the German Röntgen Society gave it the designation of '1 Röntgen' or 1 R., and it is defined nowadays as follows:

> The absolute unit of Röntgen ray dosage is given by that quantity of Röntgen ray energy which, by irradiating 1 c.cm. of air at a temperature of 18° C.[1] and a barometric pressure of 760 mm., when full use is made of all the electrons in the air

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[1] At the International Stockholm Congress in 1928 this was made 0° C. for the international unit.

and when all rays scattered from the walls of the chamber are excluded, produces such a degree of conductivity that the quantity of electricity passing with a saturation current shall measure one electrostatic unit. This unit of dosage is called a Röntgen unit, and is denoted by the letter R.

The State Physico-technical Institute has undertaken to work out the R. unit in practice, and the calibration of measuring apparatus to measure in R. units can be carried out at any time there or at the gauging stations attached to the Institute and authorized by it.

IV

METHODS OF MEASUREMENT

As has already been pointed out, one single measurement only is necessary for work with the accompanying tables—the estimation of the percentage deep dose, or P.D.D. All other values for all other requirements, such as the effective dose (E.D.) or the practical dose (P.D.), may be obtained from the tables.

The percentage deep dose can be measured by three methods:

1. The iontometric method.
2. The photographic method, and
3. Measurement with the selenium cell;

the order in which they are given being that of their respective reliability.

1. The Iontometric Method.

i. *The Principle.*

For measuring the ionization produced by X-rays one of two instruments is necessary:

1. The electrometer, or
2. The galvanometer.

1. *The electrometer.* The principle of electrometric estimation is illustrated in Fig. 13, where L is the electrometer. It consists of a fixed plate b and a moving plate a, and is charged by means of an electric machine or battery B of suitable potential. The moving pointer a is repelled when the fixed plate b is charged, and takes up a certain position on a scale c. The electrometer is connected to the ionization chamber I, the casing of which is earthed.

When ionization takes place in I through its irradiation with X-rays, the charge in the electrometer goes to earth and the pointer swings back. The rapidity with which the electrometer discharges can be measured with a stop-watch; it is the measure of the ionization in the chamber *I*, the extent of which depends upon the radiation energy absorbed in the chamber *I*.

Ionization chambers are made of aluminium, or horn, or paper covered with graphite, and to be effective should contain only a small volume of air. This principle of electrometric measurement forms the basis of Szillard's 'iontoquantimeter' (developed into its present form by Friedrich, Wintz and Chaoul), Wulf's ionometer, Martius's ionometer, and Hammer's dosimeter. The three last differ from the iontoquantimeter only in employing a thread or gold-leaf electrometer in place of one with a pointer.

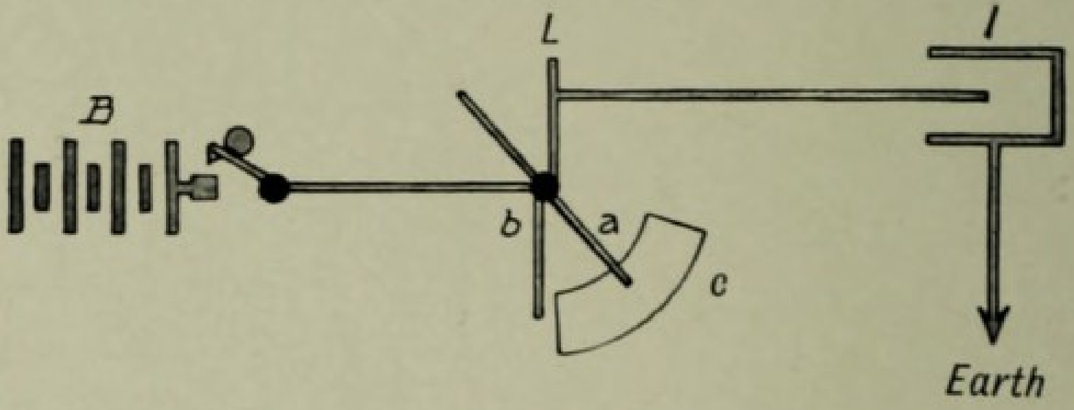

Fig. 13.

2. *The galvanometer.* The principle of galvanometric measurement is illustrated in Fig. 14. A galvanometer *G* is connected between a battery *B* and the inner electrode of the ionization chamber *I*. So long as no ionization takes place in the chamber *I*, no current can flow from the battery *B* through the galvanometer. If, however, ionization takes place, a current will flow through the chamber *I* to earth. The magnitude of this ionization current is shown on the galvanometer. The amount of deflection of the needle will depend upon the extent of the ionization in the chamber, and this depends upon the amount of radiation energy absorbed in the chamber. The deflection of the instrument is a measure of the ionization.

Instruments constructed on this principle have the advantage of allowing the dose to be determined with ease. The Siemens and Halske dosimeter is constructed on similar lines, and has the same advantage as a galvanometer of indicating the dose with a pointer. This is secured by passing the current from the ionization chamber through a high resistance and measuring the tension at its terminal. By the use of a valve galvanometer, the chief parts of which consist of an amplifying valve with an incandescent kathode and an ampèremeter measuring the anodal current, an extremely accurate reading is obtained.

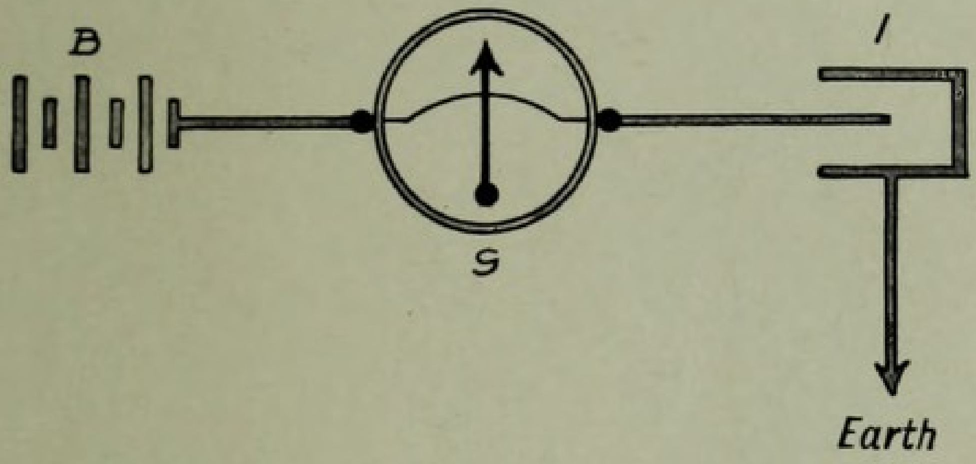

Fig. 14.

ii. *The measurement of the percentage deep dose.*

1. *The estimation of the superficial dose D_0.* The ionization chamber *I* is placed at a distance of 23 cm. from the source of rays, the focal distance from the surface. Immediately in front of it is placed a diaphragm *B*, the aperture of which is 6 × 8 cm., corresponding with the size of the normal field of incidence.

Between the diaphragm *B* and the tube, at the ordinary working distance, is placed the filter *C*, which is to be employed for the treatment to be given. Behind the chamber *I* is placed a block of wax, *S*, the object of which is to act as a scattering body so that the dose measured in the chamber shall be as nearly as possible that received by the patient. The dimensions of the wax block *S* should be not less than 20 × 5 cm. It is easy enough to cast these blocks as required; the best mixture consists of 50 parts of wax, 48 parts of paraffin wax, and 2 parts of liquid paraffin. If more exact measurements are required it is better to use water 'phantoms', in which the ionization chamber (which should be made watertight) is submerged to the required depth by means of a mechanical device. If the estimations are being made with an electrometer, the operator measures with a stop-watch the time it takes the pointer to return over a given arc of the scale. A series of not less than five readings should be taken and the average extracted. This average time t is a measure of the superficial dose D_0, and

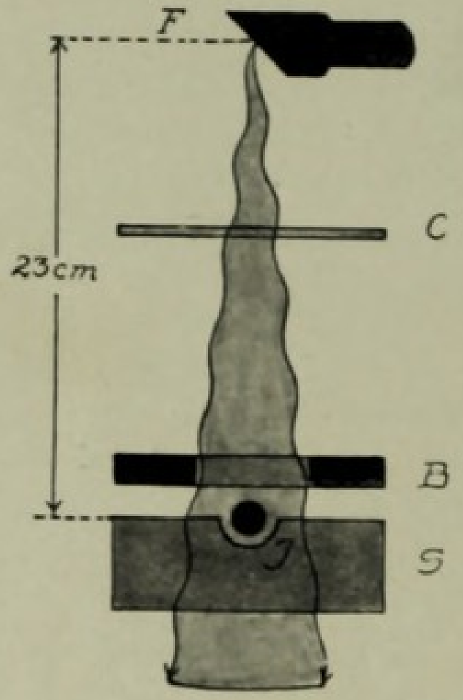

Fig. 15.

$$D_0 = \frac{1000}{t} \quad . \quad . \quad . \quad . \quad (17)$$

The unit 1000 is an arbitrary one, and the values of the doses, measured in terms of $\frac{1000}{t}$, are relative.

If a galvanometer or a Siemens and Halske dosimeter is used the deflection of the pointer is read, and the corresponding value of the dose D_0 obtained from the tables which are supplied with instruments of this kind.

2. *The estimation of the deep dose* D_1. The ionization chamber *I* is placed at a focal-depth distance, F.D. of 33 cm., and a block of wax 10 cm. thick is placed in front of it (Fig. 16).

In front of the block of wax is placed the diaphragm B with an aperture of 6 × 8 cm., again giving the normal field of incidence. Between the tube and the diaphragm, at the practical working distance, is placed the filter which is to be used in the particular treatment. Behind the ionization chamber I is placed, as before, the dispersing body S, so that the dose measured in the chamber I will be as nearly as possible the dose received by the patient.

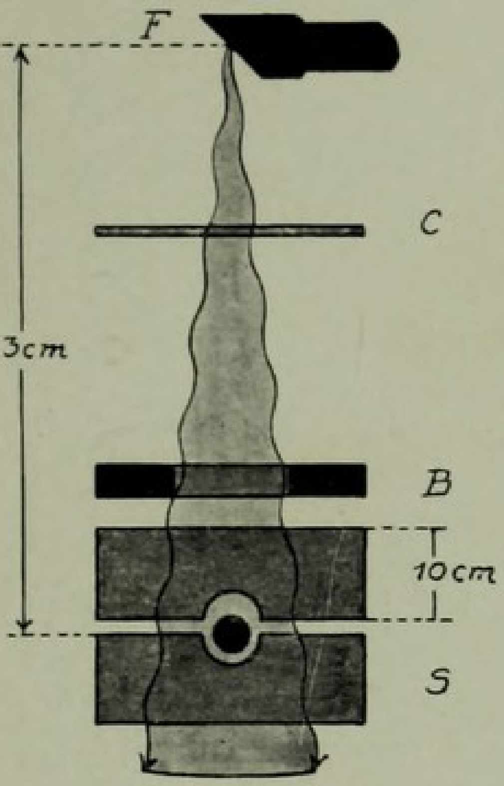

Fig. 16.

If an electrometer is used, the time taken by the pointer to swing back over the given arc is taken with a stop-watch, just as in estimating the superficial dose D_0; here again not less than five readings are taken and the average calculated. This average t_1 is the measure of the deep dose D_1 and

$$D_1 = \frac{1000}{t_1} \quad . \quad . \quad . \quad . \quad (18)$$

Here also the time t_1 is related to the unit 1000, and the dose values are relative.

If a galvanometer or a Siemens and Halske dosimeter is used the deflection of the pointer is read, and the relative value of the dose D_1 is calculated from the tables supplied with the instrument.

3. *Calculations from these results.* When D_0 and D_1 have been obtained by these methods, the percentage deep dose, P.D.D., is worked out from the equation:

$$\text{P.D.D.} = \frac{D_1}{D_0} \quad . \quad . \quad . \quad . \quad (19)$$

Supposing that D_0 has been found by the electrometer to measure 87·7 and D_1 14, then

$$\frac{D_1}{D_0} = \frac{14·0}{87·7} = 0·16 \quad . \quad . \quad . \quad (20)$$

D_0 being 100%, the P.D.D. is 16%.

If the galvanometer reading for D_0 is 70 and for D_1 is 14, then

$$\frac{D_1}{D_0} = \frac{14·0}{70·0} = 0·20 \quad . \quad . \quad . \quad . \quad (21)$$

so that, D_0 being 100%, the P.D.D. is 20%.

2. The Photographic Method.

i. *The Principle.*

The photographic method is one of the oldest methods of measuring the quality and quantity of a beam of X-rays. The measure here is the depth of the darkening under X-rays of a photographic plate; under constant experimental conditions this depends upon the intensity of the rays and the duration of the exposure. This method has fallen out of use for a good many years because of several drawbacks, but in its use here for the estimation of the percentage deep dose the sources of error are obviated. One of the most formidable of these is selective absorption in the photographic plate, and it is therefore necessary to maintain the quality of the rays constant. It should be borne in mind that in spite of the improvements which have been made here, the photographic method is no more than a makeshift, and acçurate measurement must be undertaken by the iontometric methods.

ii. *The estimation of the percentage deep dose.*

1. *The estimation of the superficial dose D_0.* The arrangement of the apparatus for measuring the superficial dose D_0 is shown in Fig. 17.

F is the focus of the X-ray tube, *C* the filter, *T* the cone,

R the light-sensitive strip ('Kienböck strip'), and S a block of wax acting as a scattering body behind it of the same dimensions as the block in the iontometric estimations. The light-sensitive strip may be exposed in a perfectly normal manner with the ordinary X-ray apparatus and the cone at 23 cm.

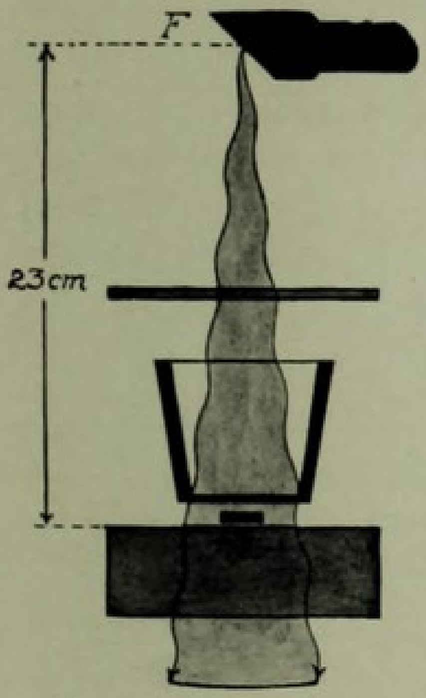

Fig. 17.

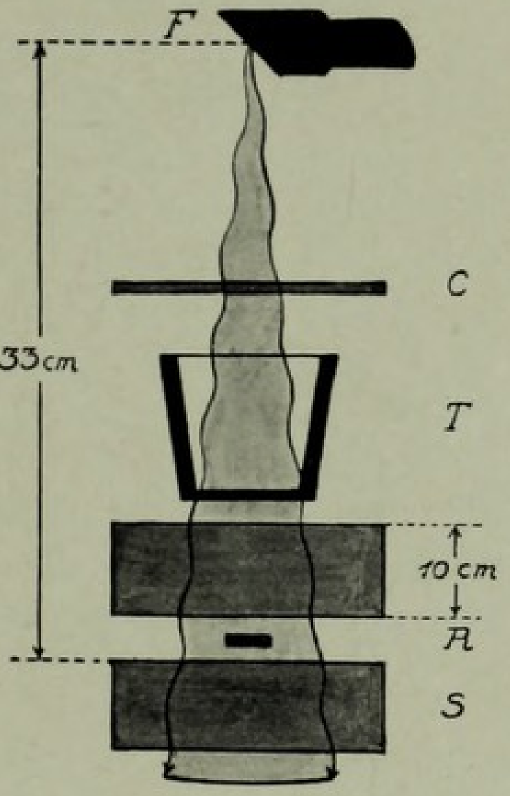

Fig. 18.

from the focus, giving a field of incidence of 6 × 8 cm. Five Kienböck strips are exposed for different periods, as follows:

i. 80 seconds.
ii. 90 ,,
iii. 100 ,,
iv. 110 ,,
v. 120 ,,

These times may be made longer or shorter according to the output of the tube and the penetrating power of the rays.

2. *The estimation of the deep dose* D_1. The arrangement of the apparatus for estimating the deep dose D_1 is set out in Fig. 18.

F is again the focus of the X-ray tube, C the filter required for the particular irradiation, T the cone, R the Kienböck strip, and S the scattering body behind it. Over the sensitive strip R is placed a wax block 10 cm. thick, of the same size as those used in iontometric measurement.

The sensitive strip R, behind the 10 cm. block of wax, is now irradiated for 500 seconds, or, if the penetrating power of the rays is high, for 400 seconds.

3. *Calculations from these results.* Having irradiated the five Kienböck strips in this way for the estimation of the surface dose D_0 and the sixth strip for the estimation of the deep dose D_1, all six strips are developed in the same bath together for the same period. After development they are washed, fixed and dried in the same way. Then the five strips exposed to the surface dose are examined to see which of them is darkened to the same depth as the sixth, which has been exposed to a dose at 10 cm. depth. From the ratio between the times of exposure of the two corresponding strips it is possible to determine how much of the surface dose has penetrated to a depth of 10 cm.

$$\text{P.D.D.} = \frac{t_0}{t_1} \qquad . \quad . \quad . \quad . \quad (22)$$

when t_0 is the time of exposure of the surface strip and t_1 the time of exposure of the strip exposed at 10 cm. depth. If, for example, it is found that the time $t_0 = 100$ seconds and $t_1 = 500$ seconds, then

$$\text{P.D.D.} = \frac{100}{500} = 0{\cdot}20 \qquad . \quad . \quad . \quad (23)$$

If D_0 is taken as 100%, then the P.D.D. is 20%.

3. The Selenium Cell Method.

i. *The Principle.*

It is well known that the electrical conductivity of selenium alters under the influence of light. A similar change in its conductivity occurs when selenium is exposed to X-rays. In order to measure radiation by means of this property, use is made of specially-constructed selenium cells, in which the fatigue-effect so often observed in selenium cells does not occur so quickly. The principle of this method of measurement is set out schematically in Fig. 19.

S is the box for receiving the rays, with the selenium cell built into it, *G* is a galvanometer, and *B* a battery. The selenium cell *S*, the galvanometer *G*, and the battery *B* form a closed circuit, the resistance of which is chiefly that of the selenium cell. As soon as X-rays reach the cell its resistance is decreased, and the galvanometer needle is deflected accordingly. The decrease in the resistance of the cell is directly proportional to the quantity of rays reaching it.

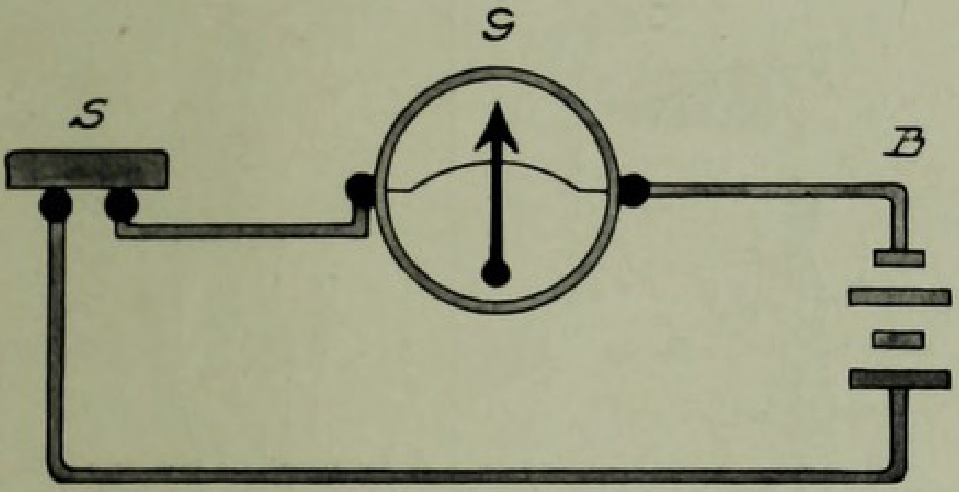

Fig. 19.

ii. *The estimation of the percentage deep dose.*

1. *The estimation of the surface dose D_0.* The arrangement of the apparatus for measuring the surface dose D_0 is shown in Fig. 20. *F* is the focus of the X-ray tube, *C* the filter, *T* the cone at 23 cm. with a field of incidence of 6 × 8 cm., *R* the receiver for the rays connected with the indicating instrument, and *S* the scattering-body behind. The last should have the same dimen-

sions as that used for the iontometric measurements. The deflection of the galvanometer pointer is then measured and found to be F_0.

2. *The estimation of the deep dose* D_1. The apparatus for estimating the deep dose D_1 is shown in Fig. 21.

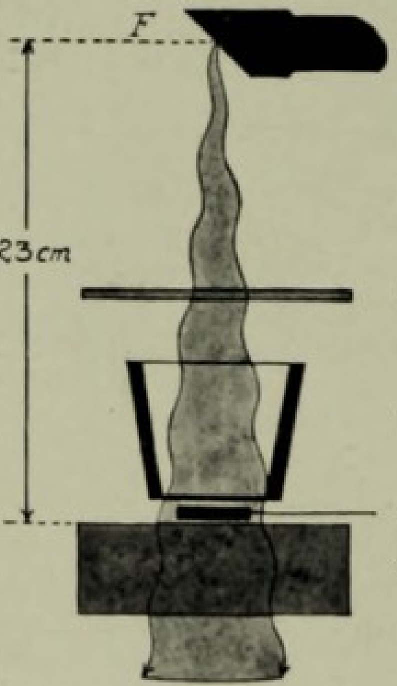

Fig. 20.

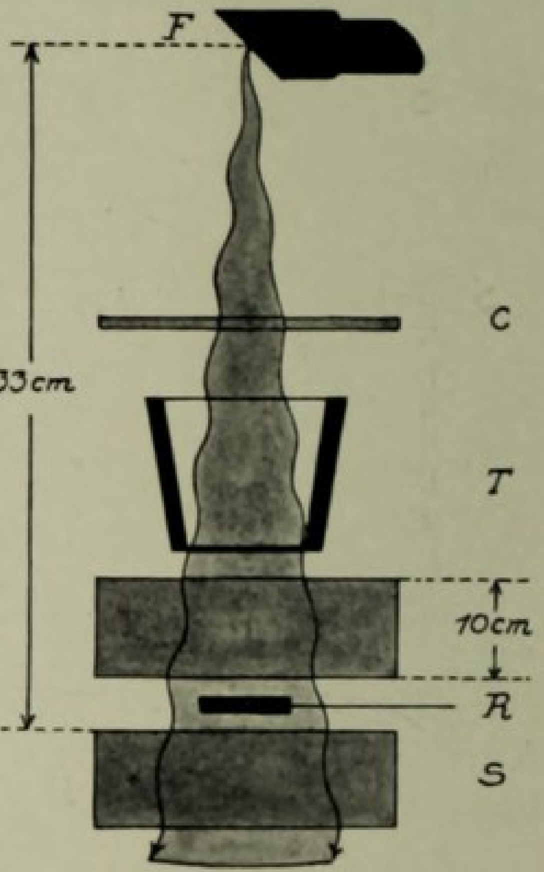

Fig. 21.

F is again the focus of the X-ray tube, C the filter in use for the given irradiation, T the cone, R the receiver connected to the galvanometer, and S the scattering-body behind it. Here, again, R has in front of it a wax block 10 cm. thick and of the same dimensions as those used for the iontometric measurements. The swing of the galvanometer is now measured and found to be F_1.

3. *Calculation from these results.* Having by these means obtained the relative values F_0 and F_1 for D_0 and D_1, the

percentage deep dose, P.D.D., is calculated from the equation

$$\text{P.D.D.} = \frac{F_1}{F_0} \quad . \quad . \quad . \quad . \quad (24)$$

Supposing F_0 is 30 divisions of the scale and F_1 is 5 divisions, then

$$\text{P.D.D.} = \frac{5}{30} = 0{\cdot}16 \quad . \quad . \quad . \quad . \quad (25)$$

If D_0 is taken as 100%, the P.D.D. is 16%.

V

THE DOSAGE TABLES

The following dosage tables fall into three groups:

I. The first group unites all the tables by which the surface dose for any required focal distance from the surface can be ascertained when the surface dose at a focal distance of 23 cm. is known. It also contains the tables for determining the time of irradiation at any required distance when the time at 23 cm. is known, and those by which it is possible to calculate the space irradiated by a bundle of rays of given dimensions.

II. The second group are used for calculating the absorption conditions in any given stratum when the quality of the rays is known.

III. The third group unites all the tables for ascertaining the practical dose at any required depth for any given focal distance from the surface, when the quality of the rays and the field of incidence are known.

Abbreviations used in the Tables

F.S.	distance of focus from the surface.
F.D.	distance of focus from the depth.
p.	the intensity factor.
z.	the time factor.
q.	the space factor.
dJ.	the density of the bundle reduced in accordance with the law of distance (Inverse Square Law).
r.	the factor of absorption in the overlying stratum of 1 cm., expressed as a percentage of dJ.
F.	the field of incidence on the skin, in square centimetres.
m.	the correction factor for the overlying stratum of 1 cm. with a variable field of incidence F.
n.	the correction factor for the variable field of incidence F.
P.D.D.	the percentage deep dose.
E.D.	the effective dose.
P.D.	the practical dose.

Other abbreviations used, especially in the additional Tables, are explained in the instructions which precede each group of dosage tables.

1. First Group of Dosage Tables.

a. Instructions for the use of Table I. If, at a focal-surface distance of 23 cm., there is projected on to the surface that amount of energy F_0 which is necessary to constitute the unit skin dose, U.S.D., then the energy Fb which will be present when the focal distance from the surface, F.S., is equal to b cm. can be calculated from the equation:

$$F_b = F_0 \times p \quad . \quad . \quad . \quad . \quad (26)$$

Table I gives values for p with a F.S. from 23 cm. to 100 cm.

A numerical example will illustrate this further. Let the surface energy F_0 at a F.S. of 23 cm. equal 100%. If, now, we desire to know the magnitude of the surface energy F_b at a F.S. of 60 cm., we look in Table I for the value of p at 60 cm. F.S. It is 0·15. Thus at a F.S. of 60 cm. the surface energy F_b is:

$$\begin{aligned} F_b &= 100\% \times 0{\cdot}15 \quad . \quad . \quad . \quad (27) \\ &= 15\%. \end{aligned}$$

If the time necessary to give a unit skin dose (U.S.D.) at F.S.= 23 cm. is t_0, then the time t_b required to give the U.S.D. at a distance b is given by

$$t_b = t_0 \times z \quad . \quad . \quad . \quad . \quad (28)$$

Values for z at a F.S. of 23 cm. to 100 cm. are to be found in Table I. If, for example, the U.S.D. is reached with a F.S. of 23 cm. in 20 minutes, it will be reached at a F.S. of 60 cm. in the time t_b.

$$\begin{aligned} t_b &= 20 \times 6{\cdot}81 \text{ minutes} \quad . \quad . \quad . \quad (29) \\ &= 136 \text{ minutes.} \end{aligned}$$

TABLE I

FS in cm	p	z
23	1·00	1·00
25	0·85	1·18
28	0·67	1·48
30	0·58	1·70
35	0·43	2·32
40	0·32	3·02
45	0·26	3·83
50	0·21	4·73
55	0·17	5·72
60	0·15	6·81
65	0·12	7·99
70	0·11	0·26
75	0·09	10·63
80	0·08	12·10
85	0·07	13·66
90	0·065	15·31
95	0·060	17·09
100	0·055	18·89

b. Instructions for the use of Tables II–IX.

Tables II–IX serve for the same calculations as Table I but are worked out for every centimetre, and at the same time, in addition to interpolation of Table I, enable the space irradiated in any instance to be calculated.

A few examples will provide sufficient explanation.

If the surface energy F_0 is developed at a focal distance, F.S., of 23 cm., the surface energy F_b at a focal distance, F.S., of 37 cm. may be calculated from Table II, as follows:

$$F_b = F_0 \times p_{37} \quad . \quad . \quad . \quad . \quad (30)$$

The value for p in Table II when F.S. = 37 is

$$p_{37} = 0{\cdot}380 \quad . \quad . \quad . \quad (31)$$

If $F_0 = 100\%$ then

$$\begin{aligned} F_b &= 100\% \times 0{\cdot}380 \quad . \quad . \quad . \quad (32) \\ &= 38\% \end{aligned}$$

Again, if the surface energy is F_0 at a focal distance, F.S., of 23 cm., the surface energy F_b at a focal distance, F.S., of 63 cm. is obtained in the following way: The value of the surface energy F'_b at F.S. 60 cm. is found with the help of Table I, which gives the value for p at F.S. 60 cm. as

$$p_{60} = 0{\cdot}15 \quad . \quad . \quad . \quad . \quad (33)$$

If we make F_0 be 100%, then

$$\begin{aligned} F'_b &= 100\% \times 0{\cdot}15 \quad . \quad . \quad . \quad (34) \\ &= 15\% \end{aligned}$$

The value of p_{63} at a F.S. of 63 cm. is now turned up in Table V. It is

$$p_{63} = 0{\cdot}907 \quad . \quad . \quad . \quad . \quad (35)$$

The surface energy F_b at a distance of 63 cm. is then calculated from the equation:

$$F_b = F'_b \times p_{63} \quad . \quad . \quad . \quad . \quad (36)$$

By substituting in this equation the value of 15%, which has been found for F'_b, we get:

$$\begin{aligned} F_b &= 15\% \times 0{\cdot}907 \quad . \quad . \quad . \quad (37) \\ &= 13{\cdot}6\% \end{aligned}$$

If the time it takes to reach a surface energy F_0 at a focal-surface distance, F.S., of 23 cm. be t_0, the time t_b which it takes to reach the same surface energy F_0 with a F.S. of 37 cm. is calculated as follows:

$$t_b = t_0 \times z_{37} \qquad . \quad . \quad . \quad (38)$$

On turning up the value of z_{37} in Table II we find:

$$z_{37} = 2{\cdot}58 \qquad . \quad . \quad . \quad (39)$$

If, for example, the time t_0 is 20 minutes, i.e. the time which it takes to reach the surface unit dose, S.U.D., at a distance of 23 cm., then t_b at a distance of 37 cm. will be

$$\begin{aligned} t_b &= 20 \times 2{\cdot}58 \text{ minutes} \qquad . \quad . \quad . \quad (40) \\ &= 52 \text{ minutes} \end{aligned}$$

Or, supposing that at a surface distance of 23 cm. the time t_0 required to reach the S.U.D. be 20 minutes, and it is desired to know what time t_b is necessary to give the S.U.D. at a focal-surface distance of 63 cm., the calculation is as follows: from Table I is taken the time t_b' which is required to give the S.U.D. at 60 cm. F.S. The time factor z_{60} is

$$z_{60} = 6{\cdot}81 \qquad . \quad . \quad . \quad . \quad (41)$$

The time t_b' is therefore:

$$\begin{aligned} t_b' &= 20 \times 6{\cdot}81 \text{ minutes} \qquad . \quad . \quad . \quad (42) \\ &= 136 \text{ minutes} \end{aligned}$$

The time factor z_{63} is now turned up in Table V. It is

$$z_{63} = 1{\cdot}1 \qquad . \quad . \quad . \quad . \quad . \quad (43)$$

The time t_b which is necessary to give the S.U.D. at 63 cm. distance is therefore

$$t_b = t_{b63}' \times z_{63} \qquad . \quad . \quad . \quad . \quad (44)$$

Substituting in this equation the value of 136 minutes which has been found for t_b', we get:

$$\begin{aligned} t_b &= 136 \times 1{\cdot}1 \text{ minutes} \qquad . \quad . \quad . \quad (45) \\ &= 149 \text{ minutes} \end{aligned}$$

It is likewise possible to calculate on the basis of these examples the surface energy and the time necessary at all focal-surface distances from F.S. 23 cm. to F.S. 120 cm. With the help of the spatial factors which are also given in the Tables under q, it is possible to calculate the amount of body space that is being irradiated at any focal-surface distance and with a field of incidence of any size.

If it is desired to know the size of an irradiated body R with a given focal-surface distance, F.S., and a field of incidence F sq. cm. down to a focal-depth distance, F.D., we use the formula:

$$R = \tfrac{1}{3}\,(F \times q_{FD} \times FD) - \tfrac{1}{3}\,(F \times FS)\ \text{cm}^3 \quad . \quad (46)$$

The use of this formula can be illustrated by a numerical example: Let the given focal-surface distance, F.S., be 40 cm. and the field of incidence 10 × 15 cm. so that $F = 150$ sq. cm. It is desired to know the size of the body space irradiated to a focal-depth distance F.D. of 54 cm. The q factor for F.D. of 54 cm. is turned up in Table III and is

$$q_{FD} = 1{\cdot}82 \quad . \quad . \quad . \quad . \quad (47)$$

By substituting the given values for F., F.S., and F.D. and that obtained from Table III for q_{FD} in equation 47, the size of the irradiated body R is found to be:

$$\begin{aligned} R &= \tfrac{1}{3}\,(150 \times 1{\cdot}82 \times 54) - \tfrac{1}{3}\,(150 \times 40)\ \text{cm.}^3 \qquad (48)\\ &= (4914 - 2000)\ \text{cm.}^3\\ &= 2914\ \text{cm.}^3 \end{aligned}$$

R is in cubic centimetres when F.S. and F.B. are in centimetres and F is in square centimetres. In the same way it is possible to calculate the size of all other irradiated strata with the aid of these Tables.

TABLE II

FS	p	z	q	FS	p	z	q
23	1·000	1·00	1·00	**30**	1·000	1·00	1·00
24	0·918	1·08	1·08	31	0·936	1·06	1·06
25	0·846	1·18	1·18	32	0·878	1·13	1·13
26	0·782	1·27	1·27	33	0·826	1·21	1·21
27	0·725	1·37	1·37	34	0·778	1·27	1·27
28	0·674	1·48	1·48	35	0·734	1·35	1·35
29	0·629	1·58	1·58	36	0·694	1·44	1·44
30	0·587	1·69	1·69	37	0·658	1·52	1·52
31	0·554	1·81	1·81	38	0·626	1·61	1·61
32	0·516	1·93	1·93	39	0·591	1·69	1·69
33	0·486	2·05	2·05	40	0·562	1·77	1·77
34	0·457	2·18	2·18	41	0·535	1·86	1·86
35	0·431	2·31	2·31	42	0·510	1·96	1·96
36	0·408	2·40	2·40	43	0·486	2·05	2·05
37	0·380	2·58	2·58	44	0·464	2·15	2·15
38	0·366	2·72	2·72	45	0·444	2·28	2·28
39	0·348	2·87	2·87	46	0·425	2·35	2·35
40	0·324	3·07	3·07	47	0·407	2·45	2·45
41	0·314	3·17	3·17	48	0·390	2·56	2·56
42	0·299	3·33	3·33	49	0·374	2·66	2·66
43	0·280	3·47	3·47	50	0·360	2·77	2·77

TABLE III

FS	p	z	q	FS	p	z	q
35	1·000	1·00	1·00	**40**	1·000	1·00	1·00
36	0·945	1·06	1·06	41	0·951	1·05	1·05
37	0·894	1·12	1·12	42	0·906	1·10	1·10
38	0·848	1·18	1·18	43	0·865	1·15	1·15
39	0·805	1·26	1·26	44	0·830	1·21	1·21
40	0·765	1·31	1·31	45	0·790	1·26	1·26
41	0·728	1·37	1·37	46	0·756	1·32	1·32
42	0·690	1·44	1·44	47	0·724	1·38	1·38
43	0·662	1·51	1·51	48	0·695	1·42	1·42
44	0·632	1·58	1·58	49	0·666	1·50	1·50
45	0·604	1·65	1·65	50	0·640	1·56	1·56
46	0·578	1·73	1·73	51	0·611	1·63	1·63
47	0·554	1·80	1·80	52	0·591	1·69	1·69
48	0·532	1·88	1·88	53	0·569	1·75	1·75
49	0·510	1·96	1·96	54	0·548	1·82	1·82
50	0·490	2·00	2·00	55	0·528	1·89	1·89
51	0·470	2·08	2·08	56	0·510	1·96	1·96
52	0·453	2·16	2·16	57	0·492	2·03	2·03
53	0·436	2·24	2·24	58	0·475	2·10	2·10
54	0·420	2·34	2·34	59	0·459	2·17	2·17
55	0·404	2·40	2·40	60	0·444	2·25	2·25

TABLE IV

FS	p	z	q	FS	p	z	q
45	1·000	1·00	1·00	**50**	1·000	1·00	1·00
46	0·956	1·04	1·04	51	0·961	1·04	1·04
47	0·916	1·08	1·08	52	0·924	1·08	1·08
48	0·878	1·14	1·14	53	0·889	1·12	1·12
49	0·843	1·18	1·18	54	0·857	1·16	1·16
50	0·801	1·23	1·23	55	0·826	1·21	1·21
51	0·777	1·28	1·28	56	0·797	1·25	1·25
52	0·748	1·33	1·33	57	0·769	1·30	1·30
53	0·724	1·39	1·39	58	0·743	1·35	1·35
54	0·699	1·44	1·44	59	0·718	1·40	1·40
55	0·668	1·49	1·49	60	0·692	1·44	1·44
56	0·645	1·55	1·55	61	0·671	1·49	1·49
57	0·623	1·60	1·60	62	0·650	1·53	1·53
58	0·601	1·66	1·66	63	0·629	1·58	1·58
59	0·581	1·72	1·72	64	0·610	1·64	1·64
60	0·562	1·78	1·78	65	0·592	1·70	1·70
61	0·544	1·84	1·84	66	0·574	1·76	1·76
62	0·526	1·89	1·89	67	0·556	1·81	1·81
63	0·510	1·96	1·96	68	0·541	1·85	1·85
64	0·497	2·02	2·02	69	0·525	1·90	1·90
65	0·479	2·09	2·09	70	0·510	1·96	1·96

TABLE V

FS	p	z	q	FS	p	z	q
55	1·000	1·00	1·00	**60**	1·000	1·00	1·00
56	0·964	1·04	1·04	61	0·967	1·03	1·03
57	0·931	1·08	1·08	62	0·936	1·06	1·06
58	0·899	1·12	1·12	63	0·907	1·10	1·10
59	0·870	1·16	1·16	64	0·878	1·14	1·14
60	0·840	1·20	1·20	65	0·852	1·18	1·18
61	0·813	1·24	1·24	66	0·826	1·22	1·22
62	0·787	1·28	1·28	67	0·800	1·26	1·26
63	0·762	1·32	1·32	68	0·778	1·30	1·30
64	0·738	1·36	1·36	69	0·756	1·33	1·33
65	0·713	1·40	1·40	70	0·734	1·37	1·37
66	0·694	1·45	1·45	71	0·712	1·40	1·40
67	0·673	1·49	1·49	72	0·694	1·44	1·44
68	0·658	1·53	1·53	73	0·675	1·48	1·48
69	0·635	1·58	1·58	74	0·659	1·52	1·52
70	0·617	1·63	1·63	75	0·640	1·56	1·56
71	0·600	1·68	1·68	76	0·623	1·60	1·60
72	0·583	1·73	1·73	77	0·607	1·65	1·65
73	0·567	1·77	1·77	78	0·591	1·69	1·69
74	0·554	1·82	1·82	79	0·576	1·73	1·73
75	0·538	1·87	1·87	80	0·562	1·77	1·77

TABLE VI

FS	p	z	q	FS	p	z	q
65	1·000	1·00	1·00	**70**	1·000	1·00	1·00
66	0·969	1·03	1·03	71	0·972	1·03	1·03
67	0·941	1·06	1·06	72	0·959	1·06	1·06
68	0·911	1·09	1·09	73	0·919	1·09	1·09
69	0·887	1·13	1·13	74	0·894	1·12	1·12
70	0·862	1·16	1·16	75	0·871	1·15	1·15
71	0·838	1·19	1·19	76	0·852	1·18	1·18
72	0·815	1·23	1·23	77	0·827	1·21	1·21
73	0·792	1·26	1·26	78	0·805	1·24	1·24
74	0·770	1·30	1·30	79	0·785	1·27	1·27
75	0·751	1·34	1·34	80	0·765	1·31	1·31
76	0·731	1·37	1·37	81	0·746	1·34	1·34
77	0·712	1·41	1·41	82	0·728	1·37	1·37
78	0·694	1·44	1·44	83	0·711	1·40	1·40
79	0·676	1·48	1·48	84	0·694	1·43	1·43
80	0·660	1·51	1·51	85	0·678	1·46	1·46
81	0·643	1·55	1·55	86	0·662	1·50	1·50
82	0·628	1·59	1·59	87	0·647	1·54	1·54
83	0·613	1·63	1·63	88	0·632	1·58	1·58
84	0·598	1·67	1·67	89	0·618	1·62	1·62
85	0·584	1·71	1·71	90	0·604	1·65	1·65

TABLE VII

FS	p	z	q	FS	p	z	q
75	1·000	1·00	1·00	**80**	1·000	1·00	1·00
76	0·974	1·03	1·03	81	0·975	1·03	1·03
77	0·948	1·06	1·06	82	0·951	1·06	1·06
78	0·924	1·09	1·09	83	0·928	1·09	1·09
79	0·901	1·11	1·11	84	0·906	1·11	1·11
80	0·882	1·14	1·14	85	0·886	1·14	1·14
81	0·857	1·17	1·17	86	0·865	1·17	1·17
82	0·836	1·20	1·20	87	0·845	1·20	1·20
83	0·816	1·23	1·23	88	0·827	1·23	1·23
84	0·798	1·26	1·26	89	0·808	1·26	1·26
85	0·778	1·29	1·29	90	0·790	1·27	1·27
86	0·760	1·32	1·32	91	0·770	1·29	1·29
87	0·743	1·35	1·35	92	0·756	1·32	1·32
88	0·727	1·38	1·38	93	0·739	1·35	1·35
89	0·710	1·41	1·41	94	0·724	1·38	1·38
90	0·694	1·44	1·44	95	0·709	1·41	1·41
91	0·679	1·47	1·47	96	0·694	1·44	1·44
92	0·665	1·50	1·50	97	0·682	1·47	1·47
93	0·650	1·54	1·54	98	0·666	1·50	1·50
94	0·636	1·57	1·57	99	0·646	1·53	1·53
95	0·621	1·60	1·60	100	0·640	1·56	1·56

TABLE VIII

FS	p	z	q	FS	p	z	q
85	1·000	1·00	1·00	**90**	1·000	1·00	1·00
86	0·977	1·02	1·02	91	0·978	1·02	1·02
87	0·952	1·04	1·04	92	0·955	1·04	1·04
88	0·932	1·07	1·07	93	0·936	1·06	1·06
89	0·912	1·09	1·09	94	0·916	1·09	1·09
90	0·891	1·12	1·12	95	0·897	1·11	1·11
91	0·872	1·14	1·14	96	0·878	1·13	1·13
92	0·844	1·17	1·17	97	0·869	1·16	1·16
93	0·835	1·19	1·19	98	0·843	1·18	1·18
94	0·817	1·22	1·22	99	0·827	1·21	1·21
95	0·800	1·24	1·24	100	0·816	1·23	1·23
96	0·783	1·27	1·27	101	0·794	1·26	1·26
97	0·767	1·30	1·30	102	0·779	1·28	1·28
98	0·752	1·33	1·33	103	0·763	1·31	1·31
99	0·739	1·35	1·35	104	0·749	1·33	1·33
100	0·723	1·38	1·38	105	0·734	1·36	1·36
101	0·708	1·41	1·41	106	0·720	1·39	1·39
102	0·694	1·44	1·44	107	0·707	1·41	1·41
103	0·681	1·47	1·47	108	0·694	1·44	1·44
104	0·667	1·50	1·50	109	0·681	1·47	1·47
105	0·655	1·53	1·53	110	0·669	1·49	1·49

TABLE IX

FS	p	z	q	FS	p	z	q
95	1·000	1·00	1·00	**100**	1·000	1·00	1·00
96	0·979	1·02	1·02	101	0·980	1·02	1·02
97	0·959	1·04	1·04	102	0·960	1·04	1·04
98	0·939	1·06	1·06	103	0·942	1·06	1·06
99	0·920	1·08	1·08	104	0·924	1·08	1·08
100	0·902	1·11	1·11	105	0·907	1·10	1·10
101	0·884	1·13	1·13	106	0·889	1·12	1·12
102	0·867	1·15	1·15	107	0·873	1·14	1·14
103	0·850	1·17	1·17	108	0·857	1·17	1·17
104	0·834	1·20	1·20	109	0·841	1·19	1·19
105	0·818	1·22	1·22	110	0·826	1·21	1·21
106	0·803	1·24	1·24	111	0·811	1·23	1·23
107	0·788	1·26	1·26	112	0·798	1·25	1·25
108	0·778	1·29	1·29	113	0·783	1·28	1·28
109	0·759	1·31	1·31	114	0·769	1·30	1·30
110	0·745	1·34	1·34	115	0·756	1·32	1·32
111	0·732	1·36	1·36	116	0·743	1·34	1·34
112	0·720	1·38	1·38	117	0·730	1·37	1·37
113	0·706	1·41	1·41	118	0·718	1·39	1·39
114	0·694	1·44	1·44	119	0·706	1·42	1·42
115	0·682	1·46	1·46	120	0·694	1·44	1·44

2. Second Group of Dosage Tables.

a. Instructions for the use of Tables X, XI, XII.

The following Tables, X, XI, and XII, contain absorption factors obtained from numerous measurements expressed as percentages of intensity, according as it is weakened in accordance with the law of distance (*dJ*), for overlying strata (*d*) from 0–20 cm. thick. Tables X, XI, and XII provide for various qualities of radiation expressed in terms of the percentage deep dose, P.D.D., and for different fields of incidence through the effective dose, E.D. They therefore cover the conditions of absorption in different overlying strata (*d*) and form at the same time a basis for an approximate calculation of the practical effective dosage of the third group of dosage tables.

If, for example, it is desired to know what practical dose, P.D., arrives at a depth of 8 cm. with a focal-surface distance, F.S., of 40 cm., i.e. with a focal-depth distance of 48 cm., the value of F_b for a distance of 48 cm. is turned up in Table III. This gives the surface energy F_0 for a focal-distance, F.S., of 40 cm.:

$$F_b = F_0 \times p \quad . \quad . \quad . \quad . \quad (49)$$

From Tables X, XI, or XII is obtained the absorption factor *r* for an overlying stratum of 8 cm. with a radiation of quality P.D. or E.D. The amount of radiation *S* lost in this stratum (*d*) of 8 cm. is expressed in the equation

$$S = p \times r \quad . \quad . \quad . \quad . \quad (50)$$

In order to arrive at the effective dose at 48 cm. the following equation is used:

$$\text{P.D.} = F_b - S \quad . \quad . \quad . \quad . \quad (51)$$

To illustrate this more clearly by a numerical example: if F_0 is 100%, then, substituting in equation 49 the value found for *p* in Table III, i.e. 0·695, we get

$$F_b = 100 \times 0{\cdot}695 = 69{\cdot}5\% \quad . \quad . \quad (52)$$

If the percentage deep dose, P.D.D., is 20% we get, by substituting in equation 50,

$$S = 0{\cdot}695 \times 50{\cdot}9 = 35\% \quad . \quad . \quad . \quad (53)$$

50·9 is the absorption factor *r* in an overlying stratum *d* of 8 cm. with a radiation of P.D. = 20%. This is the value for *r* given in Table X. The P.D. is now obtainable by using equation 51:

$$\text{P.D.} = 69{\cdot}5 - 35 = 34{\cdot}5\% \quad . \quad . \quad (54)$$

The values for the P.D., which may be calculated for all cases that occur in practice, are of course only approximate. They are subject to appropriate corrections which depend on the dispersion conditions obtaining at the time. Otherwise it must be clearly understood that these values are only true for the central rays. At the edge of the bundle they become smaller because of the changes in the conditions of dispersion. With small-focal skin distances, it must be noted, the values at the edge of the field are different from those with long-focal distances (cf. Chap. III, p. 12).

TABLE X

PDD (ED)	15%	16%	17%	18%	19%	20%
d	**r**	**r**	**r**	**r**	**r**	**r**
0	0·0	0·0	0·0	0·0	0·0	0·0
1	15·5	15·0	14·6	14·1	13·6	13·1
2	26·0	25·2	24·4	23·6	22·8	21·9
3	34·0	32·9	31·9	30·8	23·7	28·6
4	41·0	39·8	38·5	37·2	35·9	34·6
5	47·0	45·5	44·1	42·5	41·0	39·6
6	52·0	50·4	48·7	47·1	45·4	43·8
7	56·5	54·7	52·9	52·1	49·3	47·5
8	60·5	58·7	56·8	54·8	52·9	50·9
9	64·5	62·6	60·4	58·4	56·4	54·3
10	68·5	66·3	64·1	62·0	59·8	57·6
11	71·4	69·1	66·7	64·5	62·3	60·0
12	73·5	71·2	68·8	66·4	64·1	61·8
13	76·0	73·6	71·1	68·7	66·3	63·9
14	78·0	75·6	73·1	70·6	68·1	65·6
15	80·0	77·4	74·9	72·3	69·8	67·2
16	82·0	79·3	76·7	74·1	71·4	68·9
17	84·0	81·3	78·6	75·8	73·2	70·5
18	86·0	83·2	80·4	77·7	74·9	72·2
19	88·0	85·4	82·4	79·6	76·8	74·0
20	90·0	87·3	84·3	81·3	78·4	75·6

TABLE XI

PDD (ED)	21%	22%	23%	24%	25%	26%
d	r	r	r	r	r	r
0	0·0	0·0	0·0	0·0	0·0	0·0
1	12·6	12·1	11·6	11·2	10·7	10·2
2	21·1	20·3	19·5	18·6	17·9	17·0
3	27·6	26·5	25·4	24·3	23·2	22·1
4	33·3	32·0	30·7	29·4	28·1	26·8
5	38·1	36·6	35·1	33·6	32·1	30·6
6	42·1	40·6	38·9	37·2	35·5	33·9
7	45·8	43·9	42·1	40·3	38·5	36·7
8	49·0	47·1	45·2	43·2	41·3	39·3
9	52·2	50·2	48·1	46·0	43·9	41·9
10	55·4	53·2	51·0	48·9	46·6	44·4
11	57·7	55·5	53·2	50·9	48·7	46·3
12	59·4	57·1	54·7	52·3	49·9	47·6
13	61·4	59·0	56·7	54·2	51·7	49·2
14	63·1	60·6	58·2	55·7	53·2	50·6
15	64·6	62·1	59·5	57·0	54·3	51·8
16	66·2	63·6	61·0	58·4	55·7	53·1
17	67·7	65·2	62·4	59·7	57·1	54·3
18	69·4	66·7	63·9	61·2	58·3	55·6
19	71·2	68·3	65·5	62·6	59·8	57·0
20	72·7	68·8	66·9	63·9	61·0	58·1

TABLE XII

PDD (ED)	27%	28%	29%	30%	31%	32%
d	**r**	**r**	**r**	**r**	**r**	**r**
0	0·0	0·0	0·0	0·0	0·0	0·0
1	9·7	9·1	8·7	8·2	7·7	7·2
2	16·2	15·4	14·5	13·7	12·9	12·0
3	21·1	20·0	18·9	17·8	16·8	15·7
4	25·4	24·1	22·9	21·5	20·2	18·9
5	29·1	27·6	26·1	24·6	23·1	21·6
6	32·1	30·6	28·8	27·2	25·5	23·9
7	34·9	33·1	31·3	29·4	27·7	25·8
8	37·4	35·5	33·5	31·6	29·7	27·7
9	39·8	37·8	35·7	33·6	31·6	29·5
10	42·3	40·1	37·9	35·7	33·5	31·3
11	44·1	41·9	39·6	37·3	34·9	32·6
12	45·2	42·9	40·5	38·1	35·8	33·4
13	46·8	44·4	42·0	39·6	37·2	34·6
14	48·2	45·0	43·2	40·6	38·2	35·7
15	49·2	46·6	44·1	41·6	38·9	36·4
16	50·4	47·8	45·2	42·5	39·9	37·3
17	51·6	48·9	46·2	43·4	40·7	38·2
18	52·9	50·1	47·4	44·6	41·8	39·2
19	54·1	51·3	48·4	45·6	42·8	40·1
20	55·2	52·2	49·3	46·4	43·5	40·7

b. Instructions for the use of Tables XIII, XIV, XV, and XVI.

The following Tables, XIII, XIV, XV, and XVI, are field tables, the object of which is to enable the effect of the size of the field up to 150 sq. cm. to be taken into account in estimating the practical dose. For greater fields of incidence than 150 sq. cm. a special correction-table is appended at the end of the third group of dosage tables, giving correction factors m and n for these particular cases. The enlargement of the field of incidence F produces an increase in the practical dose, P.D. Since the following tables, XVII et seq., are based on the effective dose, E.D., it is necessary to calculate the effective dose for the particular case from the measured percentage deep dose, P.D.D., with the help of Tables XIII–XVI. This effective dose is then the qualitative basis for the estimation of the practical dose at different depths and with different focal-surface distances by the help of Tables XVII and those following. If, for example, it has been established by actual measurement that the percentage deep dose, P.D.D., is 16%, then the effective dose, E.D., with a field of incidence F, of 8 by 10 cm., or 80 sq. cm., is found from Table XIV to be 18·8% or—for practical purposes—19%. Knowing this value for the effective dose, E.D., it is possible to obtain from Table XVII and those following a complete list of practical doses for all depths and all focal-surface distances liable to be encountered in practice, the field of incidence being constant at 8 × 10 cm., or 80 sq. cm.

If the field of incidence is not 80 sq. cm., the effective dose, E.D., will be different, and other calculations will have to be made. An example will be given later.

TABLE XIII

PDD	15%	16%	17%	18%	19%	20%
F	ED	ED	ED	ED	ED	ED
	%	%	%	%	%	%
0	0·0	0·0	0·0	0·0	0·0	0·0
5	2·5	2·8	3·1	3·6	4·2	5·0
10	4·7	5·2	5·8	6·5	7·4	8·6
15	6·7	7·4	8·6	9·0	10·0	11·3
20	8·5	9·3	10·2	11·2	12·2	13·5
25	10·0	11·0	12·0	13·0	14·0	15·2
30	11·4	12·3	13·4	14·3	15·5	16·6
35	12·5	13·5	14·5	15·5	16·7	17·8
40	13·5	14·5	15·6	16·6	17·6	18·6
45	14·2	15·3	16·4	17·4	18·4	19·4
50	**15·0**	**16·0**	**17·0**	**18·0**	**19·0**	**20·0**
55	15·5	16·5	17·6	18·6	19·5	20·5
60	16·2	17·2	18·2	19·2	20·1	21·0
65	16·6	17·6	18·6	19·6	20·5	21·4
70	17·0	18·0	19·0	20·4	20·8	21·8

TABLE XIV

PDD	**15%**	**16%**	**17%**	**18%**	**19%**	**20%**
F	ED	ED	ED	ED	ED	ED
	%	%	%	%	%	%
75	17·4	18·4	19·4	20·4	21·3	22·2
80	17·9	18·8	19·8	20·8	21·6	22·6
85	18·1	19·0	20·1	21·1	22·0	23·0
90	18·4	19·4	20·4	21·4	22·3	23·2
95	18·8	19·7	20·7	21·7	22·5	23·5
100	19·0	20·0	21·0	22·0	22·8	23·8
105	19·2	20·2	21·2	22·2	23·0	24·1
110	19·5	20·5	21·5	22·5	23·3	24·3
115	19·7	20·7	21·7	22·7	23·6	24·5
120	20·0	21·0	22·0	23·0	23·8	24·8
125	20·2	21·2	22·2	23·2	24·0	25·0
130	20·4	21·4	22·4	23·4	24·2	25·2
135	20·6	21·6	22·6	23·6	24·5	25·5
140	20·8	21·8	22·8	23·8	24·7	25·7
145	20·9	21·9	22·9	23·9	24·8	25·8
150	21·0	22·0	23·0	24·0	25·0	26·0

TABLE XV

PDD	**21%**	**22%**	**23%**	**24%**	**25%**	**26%**
F	ED	ED	ED	ED	ED	ED
	%	%	%	%	%	%
0	0·0	0·0	0·0	0·0	0·0	0·0
5	5·8	7·5	8·5	10·0	11·5	13·6
10	9·8	11·1	12·7	14·1	15·2	16·1
15	12·5	14·4	15·4	16·5	17·6	18·7
20	14·8	16·0	17·2	18·3	19·3	21·3
25	16·4	17·6	18·6	19·6	20·5	21·5
30	17·8	19·0	19·8	20·7	21·6	22·5
35	18·8	19·9	20·8	21·7	22·6	23·5
40	19·8	20·8	21·7	22·6	23·6	24·6
45	20·4	21·4	22·4	23·4	24·4	25·4
50	**21·0**	**22·0**	**23·0**	**24·0**	**25·0**	**26·0**
55	21·5	22·5	23·5	24·5	25·5	26·5
60	22·0	22·8	23·8	24·8	25·8	26·8
65	22·4	23·3	24·3	25·3	26·3	27·3
70	22·8	23·7	24·7	25·7	26·7	27·7

TABLE XVI

PDD	21%	22%	23%	24%	25%	26%
F	ED	ED	ED	ED	ED	ED
	%	%	%	%	%	%
75	23·2	24·1	25·1	26·1	27·1	28·1
80	23·6	24·5	25·5	26·5	27·5	28·5
85	24·0	24·8	25·8	26·8	27·7	28·8
90	24·2	25·1	26·1	27·1	28·1	29·1
95	24·5	25·4	26·4	27·4	28·4	29·4
100	24·8	25·7	26·7	27·7	28·7	29·7
105	25·1	26·0	27·0	28·0	29·0	30·0
110	25·3	26·2	27·2	28·2	29·2	30·2
115	25·6	26·5	27·5	28·5	29·5	30·5
120	25·8	26·7	27·7	28·7	29·7	30·7
125	26·0	27·0	28·0	29·0	30·0	31·0
130	26·2	27·2	28·2	29·2	30·2	31·2
135	26·5	27·5	28·5	29·5	30·5	31·5
140	26·7	27·7	28·7	29·7	30·7	31·7
145	26·8	27·8	28·8	29·8	30·8	31·8
150	27·0	28·0	29·0	30·0	31·0	32·0

3. Third Group of Dosage Tables.

a. Instructions for the use of Tables XVII–LXIV.

The following dosage Tables, XVII–LXIV, allow the practical dose to be calculated for all cases, when the depth of the overlying stratum is between 0 and 20 cm., the focal-surface distance is between 23 and 100 cm., and the field of incidence *F* is up to 150 sq. cm., and the percentage deep dose, P.D.D., has already been calculated. The tables are used in the following manner: The percentage deep dose, P.D.D., is estimated for the radiation to be used with the help of one of the methods of measurement which have been described. Suppose that measurement gives a percentage deep dose of 16, the size of the effective dose, E.D., with the particular field of incidence *F* in use is now calculated from Tables XIII–XVI and found to be 10 × 10 cm. or 100 sq. cm., 20%. Suppose also that the focal-surface distance, F.S., to be used for the radiation is 40 cm. The practical effective dose under these circumstances at 8 cm. depth has now to be calculated. For this purpose it is necessary to turn to Table XXVI, which shows the practical dose, P.D., with an overlying stratum *d* of 8 cm. and an effective dose, 20%; this is 33·7%. In the same way it is possible to calculate the practical dose in all cases likely to be met with in practice.

If the field of incidence *F* is greater than 150 sq. cm., the values for the practical dose, P.D., as given in Tables XVII–LXIV, must be multiplied by the correction factors *m* and *n*, which are to be found in Table LXV; their use will be described later.

TABLE XVII

23 cm.	Focal-surface distance					23 cm.
ED	15%	16%	17%	18%	19%	20%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	77·9	78·3	78·7	79·1	79·5	79·9
2	62·2	62·7	63·3	63·9	64·4	64·9
3	51·5	52·2	52·8	53·5	54·1	54·7
4	42·5	43·2	44·0	44·7	45·4	46·2
5	35·5	36·3	37·1	37·9	38·7	39·5
6	29·8	30·7	31·5	32·6	33·2	34·1
7	25·3	26·2	27·1	28·0	28·9	29·8
8	21·0	21·9	22·9	23·8	24·7	25·7
9	18·1	19·1	20·0	21·1	22·0	23·0
10	15·0	16·0	17·0	18·0	19·0	20·0
11	13·0	14·0	15·1	16·1	17·1	18·1
12	11·0	12·1	13·1	14·2	15·2	16·3
13	9·6	10·7	11·7	12·8	13·9	15·0
14	8·4	9·5	10·6	11·6	12·7	13·8
15	7·2	8·3	9·4	10·5	11·6	12·7
16	6·1	7·2	8·3	9·4	10·5	11·6
17	5·1	6·2	7·3	8·4	9·5	10·6
18	4·2	5·3	6·4	7·5	8·6	9·7
19	3·5	4·0	5·7	6·8	7·9	9·0
20	2·8	3·9	5·0	6·1	7·2	8·3

TABLE XVIII

23 cm.			**Focal-surface distance**			23 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
0	% 100	% 100	% 100	% 100	% 100	% 100
1	80·3	80·7	81·1	81·5	81·9	82·3
2	65·5	66·1	66·6	67·2	67·7	68·3
3	55·4	56·1	56·7	57·4	58·0	58·7
4	46·9	47·5	48·3	49·0	49·7	50·4
5	40·3	41·1	41·9	42·7	43·5	44·3
6	34·9	35·8	36·0	37·5	38·3	39·2
7	30·7	31·6	32·5	33·4	34·3	35·2
8	26·6	27·5	28·5	29·4	30·3	31·3
9	24·0	24·9	25·9	26·9	27·8	28·8
10	21·0	22·0	23·0	24·0	25·0	26·0
11	19·1	20·2	21·2	22·2	23·2	24·2
12	17·3	18·4	19·4	20·5	21·5	22·6
13	16·0	17·1	18·2	19·2	20·3	21·4
14	14·9	15·9	17·1	18·1	19·2	20·3
15	13·7	14·8	15·9	17·0	18·1	19·2
16	12·6	13·7	14·8	15·9	17·0	18·1
17	11·7	12·8	13·9	15·0	16·1	17·2
18	10·8	11·9	13·0	14·1	15·2	16·3
19	10·1	11·2	12·3	13·4	14·5	15·6
20	9·4	10·5	11·6	12·7	13·8	14·9

TABLE XIX

23 cm.			Focal-surface distance			23 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
0	% 100	% 100	% 100	% 100	% 100	% 100
1	82·7	83·1	83·5	83·9	84·3	84·7
2	68·8	69·4	69·9	70·4	71·0	71·5
3	59·3	59·6	60·1	60·4	60·8	61·2
4	51·2	51·9	52·6	53·3	54·0	54·7
5	45·1	45·9	46·7	47·5	48·3	49·1
6	40·0	40·8	41·7	42·5	43·4	44·2
7	36·1	37·0	37·9	38·8	39·7	40·6
8	32·2	33·1	34·0	34·9	35·8	36·7
9	29·7	30·7	31·6	32·5	33·4	34·3
10	27·0	28·0	29·0	30·0	31·0	32·0
11	24·2	25·2	26·2	27·2	28·2	29·2
12	23·6	24·6	25·6	26·6	27·6	28·6
13	22·5	23·5	24·6	25·7	26·8	27·9
14	21·4	22·4	23·5	24·6	25·7	26·8
15	20·3	21·4	22·5	23·6	24·7	25·8
16	19·2	20·3	21·4	22·5	23·6	24·7
17	18·3	19·4	20·5	21·6	22·7	23·8
18	17·4	18·5	19·6	20·7	21·8	22·9
19	16·7	17·8	18·9	20·0	21·1	22·2
20	16·0	17·1	18·2	19·3	20·4	21·5

TABLE XX

30 cm.	Focal-surface distance					30 cm.
ED	15%	16%	17%	18%	19%	20%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	78·3	78·8	81·3	81·8	82·3	82·8
2	66·0	66·7	67·3	67·9	68·6	69·3
3	54·0	54·8	55·6	56·4	57·2	58·0
4	45·5	46·4	47·2	48·1	49·0	49·8
5	38·5	39·4	40·4	41·3	42·3	43·3
6	33·0	34·0	35·0	35·9	36·9	37·9
7	28·2	29·2	30·3	31·3	32·3	33·4
8	24·5	25·6	26·6	27·6	28·7	29·7
9	21·0	22·1	23·1	24·2	25·3	26·4
10	18·0	19·1	20·2	21·3	22·4	23·5
11	15·5	16·6	17·7	18·9	20·0	21·0
12	13·2	14·3	15·5	16·6	17·7	18·8
13	11·5	12·6	13·8	14·9	16·1	17·2
14	10·0	11·2	12·3	13·5	14·6	15·7
15	8·6	9·7	10·9	12·0	13·2	14·4
16	7·5	8·6	9·8	10·9	12·1	13·3
17	6·5	7·6	8·8	9·9	11·1	12·3
18	5·3	6·4	7·6	8·7	9·9	11·0
19	4·5	5·6	6·8	7·9	9·0	10·1
20	3·8	4·9	6·1	7·2	8·4	9·6

TABLE XXI

30. cm.	**Focal-surface distance**					30 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	83·3	83·8	84·3	84·8	85·3	85·8
2	69·9	70·5	71·2	71·8	72·5	73·2
3	58·8	59·6	60·4	61·2	62·0	62·8
4	50·7	51·6	52·5	53·3	54·2	55·1
5	44·2	45·0	46·9	47·9	48·8	49·8
6	38·8	39·8	40·8	41·8	42·8	43·8
7	34·4	35·4	36·4	37·5	38·5	39·5
8	30·8	31·8	32·9	33·9	35·0	36·0
9	27·4	28·5	29·6	30·6	31·7	32·8
10	24·6	25·7	26·8	27·9	29·0	30·1
11	22·2	23·3	24·5	25·6	26·7	27·8
12	19·9	21·1	22·2	23·4	24·5	25·6
13	18·3	20·0	21·2	22·4	23·5	24·6
14	16·8	18·5	20·3	21·8	22·9	23·8
15	15·5	16·6	17·8	19·9	20·1	21·2
16	14·4	15·5	16·7	17·8	19·0	20·1
17	13·4	14·5	15·7	16·8	18·0	19·1
18	12·2	13·4	14·5	15·6	16·8	17·9
19	11·3	12·4	13·6	14·8	15·9	17·0
20	10·7	11·8	13·0	14·2	15·3	16·4

TABLE XXII

30 cm.	**Focal-surface distance**					30 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
0	% 100	% 100	% 100	% 100	% 100	% 100
1	86·3	86·8	87·3	87·8	88·3	88·8
2	73·8	74·4	75·0	75·6	76·2	76·8
3	63·6	64·4	65·2	66·0	66·8	67·6
4	55·9	56·1	56·8	57·6	58·4	59·2
5	46·7	47·6	48·5	49·4	50·3	51·2
6	42·8	43·7	44·7	45·8	46·7	47·8
7	40·6	41·6	42·6	43·6	44·6	45·6
8	37·1	38·1	39·1	40·1	41·1	42·1
9	33·8	34·9	35·9	36·9	37·9	38·9
10	31·2	32·3	33·4	34·5	35·6	36·9
11	27·9	29·0	30·1	31·2	32·3	33·4
12	26·8	27·9	29·0	30·1	31·2	32·3
13	25·8	26·9	27·9	28·9	29·9	30·9
14	24·2	25·3	26·4	27·5	28·5	29·4
15	22·4	23·5	24·6	25·7	26·8	27·9
16	21·3	22·4	23·5	24·6	25·5	26·8
17	20·3	21·4	22·5	23·6	24·7	25·8
18	19·1	20·2	21·2	22·3	23·3	24·4
19	18·2	19·4	20·5	21·5	22·5	23·5
20	17·6	18·7	19·8	20·9	22·0	23·1

TABLE XXIII

35 cm.	Focal-surface distance					35 cm
ED	15%	16%	17%	18%	19%	20%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	79·8	80·5	81·0	81·5	82·1	82·7
2	66·2	66·9	67·6	68·3	69·0	70·7
3	56·0	56·8	57·7	58·2	59·4	60·2
4	47·5	48·5	49·4	50·4	51·3	52·3
5	40·5	41·6	42·6	43·7	44·7	45·8
6	35·0	36·1	37·2	38·2	39·3	40·4
7	30·2	31·3	32·5	33·6	34·7	35·9
8	26·2	27·3	28·5	29·7	30·9	32·0
9	22·4	23·6	24·8	26·0	27·2	28·4
10	19·3	20·5	21·7	22·9	24·0	25·2
11	16·8	18·0	19·2	20·4	21·6	22·9
12	14·7	15·9	17·2	18·4	19·6	20·8
13	12·7	14·0	15·2	16·5	17·7	19·9
14	11·2	12·5	13·7	14·9	16·2	17·5
15	9·8	11·0	12·3	13·5	14·8	16·0
16	8·5	9·7	11·0	12·2	13·5	14·7
17	7·3	8·5	9·7	11·0	12·3	13·5
18	6·1	7·4	8·6	9·8	11·1	12·4
19	5·0	6·3	7·5	8·7	10·0	11·3
20	4·0	5·3	6·5	7·7	9·0	10·3

TABLE XXIV

35 cm.	Focal-surface distance					35 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	83·3	83·8	84·3	84·9	85·4	86·0
2	71·5	72·1	72·8	73·6	74·3	75·0
3	61·0	61·9	62·8	63·6	64·5	65·3
4	53·2	54·2	55·2	56·2	57·1	58·0
5	46·8	47·9	48·9	50·0	51·0	52·1
6	41·5	42·6	43·6	44·7	45·8	46·8
7	37·0	38·2	39·3	40·4	41·6	42·7
8	33·2	34·4	35·6	36·8	37·9	39·1
9	29·6	30·8	32·0	33·1	34·3	35·5
10	26·4	27·6	28·8	30·0	31·2	32·4
11	24·1	25·3	26·5	27·7	28·9	30·2
12	22·1	23·3	24·5	25·7	27·0	28·2
13	20·2	21·4	22·7	23·9	25·1	26·4
14	18·7	19·9	21·2	22·4	23·7	25·0
15	17·3	18·5	19·8	21·0	22·3	23·6
16	16·0	17·2	18·5	19·7	21·0	22·2
17	14·7	16·0	17·2	18·5	19·7	21·0
18	13·7	14·9	16·2	17·4	18·7	19·9
19	12·5	13·7	15·0	16·2	17·5	18·7
20	11·5	12·7	14·0	15·2	16·5	17·7

TABLE XXV

35 cm.			**Focal-surface distance**			35 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	86·5	87·1	87·7	88·3	88·9	89·5
2	75·7	76·4	77·1	77·8	78·5	79·2
3	66·2	67·0	67·8	68·6	69·4	70·2
4	59·0	59·9	60·8	61·7	62·8	63·9
5	53·1	54·2	55·1	56·2	57·2	58·2
6	47·9	49·0	50·1	51·2	52·3	53·3
7	43·9	45·0	46·2	47·4	48·4	49·8
8	40·3	41·5	42·7	43·9	45·1	46·3
9	36·7	37·9	39·1	40·3	41·5	42·7
10	33·6	34·8	36·0	37·2	38·4	39·6
11	31·4	32·6	33·8	35·0	36·2	36·4
12	29·5	30·7	31·9	33·1	34·3	35·5
13	27·6	28·9	30·1	31·3	32·5	33·7
14	26·2	27·4	28·6	29·8	31·0	32·2
15	24·8	26·0	27·2	28·4	29·6	30·8
16	23·5	24·7	25·9	27·1	28·3	29·5
17	22·3	23·5	24·7	25·9	27·1	28·3
18	21·2	22·4	23·6	24·8	26·0	27·1
19	20·0	21·2	22·4	23·6	24·8	26·0
20	19·0	20·2	21·4	22·6	23·8	25·0

TABLE XXVI

40 cm.			**Focal-surface distance**			40 cm.
ED	15%	16%	17%	18%	19%	20%
d	PD %	PD %	PD %	PD %	PD %	PD %
0	100	100	100	100	100	100
1	81·1	81·9	82·4	83·0	83·5	84·0
2	66·6	67·3	68·2	68·9	69·7	70·4
3	57·1	58·0	58·9	59·7	60·6	61·5
4	49·0	50·0	51·0	51·9	52·9	53·9
5	41·9	43·0	43·1	44·1	45·1	46·1
6	36·3	37·4	38·6	39·7	40·8	42·0
7	31·5	32·7	33·9	35·1	36·3	37·5
8	27·5	28·7	30·0	31·2	32·5	33·7
9	23·6	24·9	26·1	27·4	28·7	29·9
10	20·5	21·8	23·1	24·4	25·7	27·1
11	17·8	19·1	20·4	21·8	23·1	24·4
12	15·7	17·0	18·4	19·7	21·0	22·3
13	13·7	15·0	16·4	17·7	19·0	20·0
14	12·0	13·3	14·7	16·0	17·4	18·7
15	10·6	12·0	13·3	14·7	16·0	17·4
16	9·2	10·6	12·0	13·3	14·7	16·1
17	7·9	9·3	10·7	12·1	13·5	14·8
18	6·7	8·1	9·5	10·9	12·3	13·7
19	5·5	6·9	8·3	9·7	11·1	12·5
20	4·4	5·8	7·2	8·6	10·0	11·4

TABLE XXVII

40 cm.	**Focal-surface distance**					40 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	84·6	85·1	85·7	86·2	86·8	87·4
2	71·1	71·9	72·6	74·3	75·1	75·8
3	62·4	63·3	64·1	65·0	65·9	66·8
4	54·9	55·9	56·8	57·8	58·8	59·8
5	47·4	48·5	49·5	50·6	51·7	52·8
6	43·1	44·3	45·4	46·6	47·7	48·8
7	38·7	39·9	41·1	42·3	43·5	44·7
8	35·0	36·3	37·5	38·7	40·0	41·2
9	31·2	32·5	33·8	35·0	36·3	37·6
10	28·3	29·6	30·9	32·2	33·5	34·8
11	25·7	27·0	28·4	29·7	31·0	32·3
12	23·7	25·0	26·3	27·7	29·0	30·3
13	21·7	23·1	24·4	25·8	27·1	28·4
14	20·1	21·4	22·8	24·1	25·5	26·8
15	18·8	20·1	21·5	22·8	24·2	25·6
16	17·5	18·9	20·2	21·6	23·0	24·4
17	16·2	17·6	19·0	20·4	21·8	23·2
18	15·1	16·5	17·9	19·3	20·7	22·1
19	13·9	15·3	16·7	18·1	19·5	20·9
20	12·8	13·2	14·6	16·0	17·4	18·8

TABLE XXVIII

40 cm.			Focal-surface distance			40 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	87·9	88·5	89·0	89·6	90·2	90·8
2	76·6	77·3	78·1	78·9	79·7	80·5
3	67·7	68·5	69·4	70·3	71·2	72·1
4	60·8	61·7	62·7	63·7	64·7	65·7
5	53·9	54·9	56·0	57·1	58·2	59·3
6	50·0	51·1	52·3	53·5	54·7	55·9
7	45·9	47·1	48·3	49·5	50·7	51·9
8	42·5	43·7	44·9	46·1	47·3	48·7
9	38·8	40·1	41·4	42·7	44·0	45·3
10	36·1	37·4	38·7	40·0	41·3	42·6
11	33·6	35·0	36·3	37·6	38·9	40·2
12	31·7	33·0	34·3	35·6	36·9	38·2
13	29·8	31·1	32·4	33·7	35·0	36·4
14	28·2	29·5	30·8	32·3	33·6	34·9
15	26·9	28·3	29·7	31·1	32·5	33·9
16	25·8	27·1	28·5	29·9	31·3	32·7
17	24·6	26·0	27·4	28·8	30·2	31·6
18	23·5	24·9	26·3	27·7	29·1	30·5
19	22·3	23·7	25·1	26·5	27·9	29·3
20	20·2	21·6	23·0	24·4	25·8	27·2

TABLE XXIX

45 cm.			Focal-surface distance			45 cm.
ED	15%	16%	17%	18%	19%	20%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	81·2	81·4	81·9	82·5	83·1	83·6
2	67·8	68·6	69·3	70·1	71·8	72·6
3	58·0	58·9	59·8	60·7	61·6	62·5
4	49·7	50·7	51·8	52·8	53·8	54·8
5	42·5	43·6	44·7	45·9	47·0	48·1
6	37·3	38·5	39·7	40·8	42·0	43·2
7	32·6	33·8	35·1	36·3	37·6	38·8
8	28·6	29·9	31·2	32·4	33·7	35·0
9	24·8	26·1	27·4	28·8	30·1	31·4
10	21·4	22·7	24·1	25·4	26·8	28·1
11	18·8	20·2	21·5	22·9	24·3	25·6
12	16·4	17·8	19·2	20·5	22·0	23·3
13	14·4	15·8	17·2	18·6	20·0	21·4
14	12·8	14·2	15·6	17·1	18·5	19·9
15	11·2	12·6	14·1	15·5	16·9	18·3
16	9·7	11·1	12·6	14·0	15·5	16·9
17	8·4	9·8	11·3	12·7	14·2	15·6
18	7·1	8·5	10·0	11·4	12·9	14·3
19	5·9	7·4	8·8	10·3	11·7	13·1
20	4·8	6·2	7·7	9·2	10·6	12·0

TABLE XXX

45 cm.	**Focal-surface distance**					45 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	84·2	84·8	85·4	85·9	86·5	87·0
2	73·4	74·1	74·9	75·6	76·4	77·2
3	63·5	64·4	65·3	66·2	67·1	68·0
4	55·9	56·9	57·9	59·0	60·0	61·0
5	49·2	50·3	51·5	52·6	53·7	54·8
6	44·4	45·6	46·7	47·9	49·1	50·3
7	40·0	41·3	42·5	43·8	45·0	46·2
8	36·3	37·6	38·8	40·1	41·4	42·7
9	32·7	34·0	35·4	36·7	38·0	39·3
10	29·5	30·8	32·2	33·5	34·9	36·3
11	27·0	28·4	29·8	31·1	32·5	33·9
12	24·7	26·1	27·4	28·8	30·2	31·6
13	22·8	24·2	25·6	27·0	28·4	29·8
14	21·3	22·8	24·2	25·6	27·0	28·4
15	19·8	21·2	22·6	24·1	25·5	26·9
16	18·3	19·8	21·2	22·7	24·1	25·5
17	17·1	18·6	20·0	21·4	22·9	24·4
18	15·8	17·2	18·7	20·1	21·6	23·1
19	14·6	16·0	17·5	18·9	20·4	21·8
20	13·5	14·9	16·4	17·8	19·3	20·7

TABLE XXXI

45 cm.	**Focal-surface distance**					45 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	87·6	88·2	88·6	89·0	89·4	89·8
2	78·9	79·7	80·2	81·7	82·2	82·7
3	69·9	70·8	71·7	72·6	73·5	74·4
4	62·1	63·1	64·1	65·1	66·1	67·1
5	55·9	57·1	58·1	59·2	60·3	61·4
6	51·5	52·6	53·8	55·0	56·2	57·4
7	47·5	48·7	49·9	51·1	52·3	53·5
8	44·0	45·2	46·4	47·6	48·8	50·0
9	40·6	42·0	43·3	44·6	45·9	46·2
10	37·6	38·9	40·2	41·5	42·8	44·1
11	35·2	36·6	38·0	39·4	40·8	42·2
12	32·9	34·3	35·7	37·1	38·5	39·9
13	31·2	32·6	34·0	35·4	36·8	38·2
14	29·9	31·3	32·8	34·1	35·6	37·1
15	27·4	28·8	30·3	31·8	33·3	34·8
16	27·0	28·4	29·5	30·7	32·0	33·4
17	25·8	27·2	28·7	30·1	31·3	32·5
18	24·5	25·9	27·3	28·7	30·1	31·5
19	23·3	24·7	26·1	27·5	28·9	30·9
20	22·2	23·6	25·0	26·4	27·8	29·2

TABLE XXXII

50 cm.			**Focal-surface distance**			50 cm.
ED	15%	16%	17%	18%	19%	20%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	81·3	81·7	82·3	82·8	83·4	84·0
2	68·8	69·4	70·2	71·0	71·8	72·5
3	58·7	59·6	60·6	61·5	62·5	63·4
4	50·7	51·8	52·8	53·9	55·0	56·0
5	43·1	44·3	45·4	46·6	47·7	48·9
6	38·4	39·6	41·0	42·2	43·5	44·7
7	33·5	34·8	36·1	37·4	38·7	40·0
8	29·2	30·5	31·9	33·2	34·6	35·9
9	25·6	27·0	28·4	29·7	31·1	32·5
10	22·4	23·8	25·2	26·6	28·0	29·4
11	19·4	20·8	22·2	23·6	25·1	26·5
12	17·2	18·6	20·1	21·5	22·9	24·3
13	15·1	16·5	18·0	19·4	20·9	22·3
14	13·4	14·9	16·3	17·8	19·2	20·6
15	11·8	13·2	14·7	16·1	17·6	19·0
16	10·3	11·7	13·2	14·6	16·1	17·5
17	8·8	10·2	11·7	13·1	14·6	16·0
18	7·6	9·0	10·5	12·0	13·4	14·9
19	6·3	7·7	9·2	10·7	12·1	13·6
20	5·1	6·6	8·0	9·5	10·9	12·4

TABLE XXXIII

50 cm.			Focal-surface distance			50 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	84·6	85·2	85·7	86·3	86·9	87·5
2	73·3	74·1	74·9	75·7	76·5	77·3
3	64·4	65·3	66·3	67·3	68·2	69·1
4	57·1	58·2	59·3	60·3	61·4	62·5
5	50·1	51·2	52·4	53·5	54·7	55·9
6	45·9	47·2	48·4	49·7	50·9	52·1
7	41·3	42·6	43·9	45·2	46·5	47·8
8	37·3	38·6	40·0	41·3	42·7	44·0
9	33·9	35·3	36·6	38·0	39·4	40·8
10	30·8	32·2	33·6	35·0	36·4	37·8
11	27·9	29·3	30·8	32·2	33·6	35·0
12	25·8	27·2	28·6	30·1	31·5	32·9
13	23·7	25·2	26·6	28·1	29·5	30·9
14	22·1	23·5	25·0	26·4	27·8	29·3
15	20·4	21·9	23·3	24·8	26·2	27·6
16	19·0	20·4	21·9	23·3	24·8	26·2
17	17·5	18·9	20·4	21·8	23·3	24·7
18	16·4	17·8	19·3	20·7	22·2	23·7
19	15·1	16·5	18·0	19·4	20·9	22·4
20	13·9	15·3	16·8	18·2	19·7	21·2

TABLE XXXIV

50 cm.			Focal-surface distance			50 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	88·1	88·6	89·2	89·8	90·2	90·8
2	78·1	78·9	79·7	80·5	81·3	82·1
3	70·1	71·0	71·9	72·8	73·7	74·6
4	63·5	64·6	65·5	66·4	67·3	68·2
5	57·0	58·2	59·2	60·2	61·2	62·2
6	53·4	54·6	55·7	56·8	57·9	59·0
7	49·1	50·4	51·6	52·8	54·0	55·2
8	45·4	46·7	47·9	49·1	50·3	51·5
9	42·2	43·5	44·8	46·1	47·4	48·7
10	39·0	40·0	41·3	42·6	43·9	45·2
11	36·4	37·8	39·1	40·2	41·5	42·8
12	34·4	35·8	37·2	38·4	39·6	40·8
13	32·4	33·7	35·1	36·5	37·9	39·1
14	30·7	32·2	33·6	35·0	36·4	37·8
15	29·1	30·5	31·9	33·1	34·5	35·9
16	27·7	29·2	30·6	32·0	33·7	34·5
17	26·2	27·6	29·0	30·4	31·8	33·2
18	25·1	26·6	28·1	29·6	31·1	32·6
19	23·8	25·3	26·8	28·3	29·8	31·3
20	22·6	24·1	25·6	27·2	28·7	30·2

TABLE XXXV

55 cm.			Focal-surface distance			55 cm.
ED	15%	16%	17%	18%	19%	20%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	81·4	81·7	82·3	82·9	83·5	84·1
2	69·2	69·7	70·6	71·5	72·4	73·3
3	61·0	61·5	61·9	62·6	63·6	64·7
4	52·3	52·5	53·6	54·7	55·8	56·9
5	44·5	45·7	47·0	48·2	49·5	50·7
6	38·9	40·2	41·6	42·9	44·3	45·6
7	33·9	35·3	36·7	38·1	39·5	40·9
8	29·6	31·0	32·5	33·1	34·4	35·9
9	25·9	27·4	28·8	30·2	31·7	33·2
10	22·7	24·2	25·7	27·2	28·7	30·2
11	20·3	21·8	23·4	24·9	26·4	27·9
12	18·0	19·5	21·1	22·6	24·2	25·7
13	15·8	17·4	18·9	20·5	22·0	23·6
14	14·1	15·7	17·2	18·8	20·4	21·9
15	12·4	14·0	15·6	17·1	18·7	20·3
16	10·8	12·4	14·0	15·6	17·2	18·7
17	9·3	10·9	12·5	14·0	15·6	17·1
18	7·8	9·4	11·0	12·6	14·2	15·8
19	6·5	8·1	9·7	11·3	12·9	14·5
20	5·3	6·9	8·5	10·1	11·7	13·3

TABLE XXXVI

55 cm.			Focal-surface distance			55 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	84·7	85·3	85·9	86·5	87·1	87·7
2	74·2	75·1	76·0	76·9	77·8	78·7
3	65·8	66·8	67·9	68·9	70·0	71·1
4	58·1	59·2	60·9	61·5	62·6	63·7
5	51·9	53·2	54·4	55·6	57·9	59·1
6	47·0	48·3	49·7	51·0	52·4	53·7
7	42·3	43·7	45·1	46·5	47·9	49·3
8	37·3	38·7	40·2	41·6	43·1	49·5
9	34·7	36·2	37·6	39·1	40·6	42·1
10	31·7	33·2	34·7	36·2	37·7	39·2
11	29·5	31·0	32·4	34·1	35·6	37·1
12	27·3	28·8	30·4	31·9	33·5	35·0
13	25·2	26·7	28·3	29·8	31·4	33·0
14	23·5	25·0	26·6	28·1	29·7	31·3
15	21·9	23·5	25·0	26·6	28·2	29·8
16	20·3	21·9	23·5	25·1	26·7	28·3
17	18·7	20·3	21·9	23·5	25·1	26·7
18	17·4	19·0	20·6	22·2	23·8	25·4
19	16·1	17·7	19·3	20·9	22·5	24·1
20	14·9	16·5	18·1	19·7	21·3	22·9

TABLE XXXVII

55 cm.			Focal-surface distance			55 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	88·3	88·9	89·5	90·1	90·6	91·1
2	79·6	80·5	81·4	82·3	83·2	84·1
3	72·1	73·2	74·1	75·2	76·2	77·2
4	64·9	66·0	67·0	68·0	69·0	70·0
5	60·4	61·6	62·7	63·8	64·9	66·0
6	55·1	56·4	57·6	58·8	60·0	61·2
7	50·7	52·1	53·5	54·9	56·3	57·7
8	46·0	47·4	48·8	50·2	51·6	53·0
9	43·6	45·0	46·4	47·8	49·2	50·6
10	40·7	42·2	43·7	45·2	46·7	48·2
11	38·7	40·2	41·7	43·2	44·7	46·2
12	36·6	38·2	39·7	41·2	42·7	44·2
13	34·5	36·1	37·6	39·1	40·6	42·1
14	32·8	34·4	35·9	37·4	38·9	40·4
15	31·4	32·9	34·4	35·9	37·4	38·9
16	29·9	31·5	33·0	34·5	36·0	37·5
17	28·3	29·9	31·5	33·1	34·6	36·1
18	27·0	28·6	30·2	31·8	33·2	34·8
19	25·7	27·3	28·9	30·5	32·1	33·7
20	24·5	26·1	27·7	29·3	30·9	32·5

TABLE XXXVIII

60 cm.	Focal-surface distance					60 cm.
ED	15%	16%	17%	18%	19%	20%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	82·0	82·6	83·3	83·9	84·5	85·1
2	69·6	70·5	71·4	72·3	73·2	74·1
3	60·1	61·2	62·3	63·3	64·4	65·5
4	51·9	53·1	54·3	55·6	56·8	58·0
5	45·0	46·3	47·7	49·0	50·4	51·7
6	39·4	40·8	42·3	43·7	45·1	46·5
7	34·8	36·3	37·7	39·2	40·7	42·1
8	30·8	32·3	33·8	35·4	36·9	38·4
9	27·0	28·5	30·1	31·6	33·2	34·7
10	23·3	24·9	26·5	28·1	29·7	31·3
11	21·9	22·5	24·1	25·8	27·4	29·0
12	18·5	20·1	21·8	23·4	25·0	26·6
13	16·3	17·9	19·6	21·0	22·7	24·3
14	14·5	16·1	17·8	19·4	21·1	22·7
15	12·8	14·4	16·1	17·7	19·5	21·1
16	11·2	12·8	14·4	16·0	17·6	19·4
17	9·8	11·4	13·1	14·7	16·4	18·0
18	8·4	10·0	11·7	13·3	15·0	16·6
19	7·0	8·6	10·3	11·9	13·6	15·2
20	5·6	7·2	8·9	10·5	12·2	13·8

TABLE XXXIX

60 cm.			Focal-surface distance			60 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
0	% 100	% 100	% 100	% 100	% 100	% 100
1	85·8	86·4	87·0	87·6	88·3	88·9
2	75·0	75·9	76·8	77·7	78·6	79·5
3	66·6	67·7	68·7	69·8	70·9	72·0
4	59·2	60·4	61·7	62·9	64·1	65·3
5	53·1	54·5	55·8	57·2	58·5	59·8
6	48·0	49·4	50·8	52·3	53·7	55·1
7	43·6	45·1	46·6	48·0	49·5	51·0
8	39·9	41·4	42·9	44·5	46·0	47·5
9	36·3	37·8	39·4	40·9	42·5	44·0
10	32·9	34·5	36·1	37·7	39·3	40·9
11	30·6	32·2	33·9	35·5	37·1	38·7
12	28·3	29·9	31·5	33·2	34·8	36·4
13	25·9	27·6	29·0	30·7	32·3	33·9
14	24·4	26·1	27·7	29·5	31·1	32·7
15	22·7	24·5	26·1	27·8	29·5	31·2
16	21·0	22·7	24·4	26·0	27·7	29·4
17	19·7	21·3	23·0	24·6	26·3	27·9
18	18·3	19·9	21·6	23·2	24·9	26·5
19	16·9	18·5	20·2	21·8	23·5	25·1
20	15·5	17·1	18·8	20·4	22·1	23·7

TABLE XL

60 cm.			Focal-surface distance			60 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	90·6	91·2	91·8	92·4	93·0	93·6
2	80·4	81·3	82·2	83·1	84·0	84·9
3	73·1	74·1	75·0	75·9	76·8	77·7
4	66·5	67·7	68·5	69·8	70·8	71·8
5	61·2	62·5	63·6	64·7	65·8	66·9
6	56·6	58·0	59·2	60·4	61·6	62·6
7	52·4	53·1	55·1	56·3	57·5	58·7
8	49·1	50·5	51·7	52·9	54·1	55·3
9	45·6	47·3	48·6	49·9	51·2	52·5
10	42·5	44·2	45·7	47·0	48·3	49·6
11	40·3	42·0	43·3	44·6	45·9	47·2
12	38·1	39·7	41·1	42·5	43·9	45·3
13	35·6	37·2	38·6	40·0	41·4	42·8
14	34·5	36·1	37·5	38·9	40·3	41·7
15	32·8	34·5	35·9	37·3	38·7	40·1
16	31·1	32·7	34·2	35·7	37·2	38·7
17	29·6	31·2	32·7	34·2	35·7	37·2
18	28·2	29·8	31·4	33·0	34·6	36·2
19	26·8	28·4	30·0	31·6	33·2	34·8
20	25·4	27·0	28·6	30·2	31·8	33·2

TABLE XLI

65 cm.			Focal-surface distance			65 cm.
ED	15%	16%	17%	18%	19%	20%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	82·0	82·6	83·3	83·9	84·6	85·2
2	69·6	70·5	71·4	72·3	73·2	74·1
3	60·1	61·2	62·4	63·5	64·6	65·7
4	51·9	53·1	54·4	55·6	56·9	58·1
5	45·4	46·8	48·2	49·5	50·9	52·3
6	39·8	41·3	42·8	44·2	45·7	47·2
7	35·2	36·7	38·3	39·8	41·4	42·9
8	31·2	32·8	34·4	35·9	37·5	39·1
9	27·3	28·9	30·5	32·2	33·8	35·4
10	24·0	25·6	27·3	28·9	30·6	32·2
11	21·2	22·9	24·5	26·2	27·8	29·5
12	19·5	21·2	22·8	24·5	26·2	27·8
13	16·9	18·6	20·3	21·9	23·6	25·3
14	14·7	16·4	18·1	19·8	21·5	23·1
15	13·2	14·9	16·6	18·3	20·0	21·7
16	11·5	13·2	14·9	16·6	18·3	20·0
17	10·1	11·8	13·5	15·2	16·9	18·6
18	8·6	10·3	12·0	13·7	15·4	17·1
19	7·2	8·9	10·6	12·3	14·0	15·7
20	5·8	7·5	9·2	10·9	12·6	14·3

TABLE XLII

65 cm.			**Focal-surface distance**			65 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
0	% 100	% 100	% 100	% 100	% 100	% 100
1	85·9	86·5	87·2	87·8	88·5	89·1
2	75·0	75·9	76·8	77·7	78·6	79·5
3	66·9	68·0	69·1	70·3	71·4	72·5
4	59·4	60·6	61·9	63·1	64·4	65·6
5	53·7	55·0	56·4	57·8	59·2	60·6
6	48·7	50·2	51·6	53·1	54·6	56·1
7	44·5	46·0	47·6	49·1	50·7	52·2
8	40·7	42·3	43·8	45·4	47·0	48·6
9	37·0	38·6	40·3	41·9	43·5	45·1
10	33·9	35·5	37·2	38·8	40·5	42·1
11	31·2	32·8	34·4	36·1	37·8	39·4
12	29·5	31·2	32·9	34·5	36·2	37·9
13	27·0	28·7	30·3	32·0	33·7	35·4
14	24·8	26·5	28·2	29·9	31·6	33·3
15	23·4	25·1	26·8	28·5	30·2	31·9
16	21·7	23·4	25·1	26·8	28·5	30·2
17	20·3	22·0	23·7	25·4	27·1	28·8
18	18·8	20·5	22·2	23·9	25·6	27·3
19	17·4	19·1	20·8	22·5	24·2	25·9
20	16·0	17·7	19·4	21·1	22·8	24·5

TABLE XLIII

65 cm.			Focal-surface distance			65 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	89·8	90·4	91·0	91·6	92·2	92·8
2	80·4	81·3	82·1	82·9	83·7	84·6
3	73·7	74·8	75·7	76·6	77·5	78·4
4	66·9	68·1	69·1	70·1	71·1	72·1
5	62·0	63·3	64·4	65·5	66·6	67·7
6	57·6	59·0	60·1	61·2	62·3	63·4
7	53·8	55·3	56·5	57·7	58·9	60·1
8	50·2	51·7	52·9	54·1	55·3	56·5
9	46·7	48·4	49·6	50·8	52·0	53·2
10	43·8	45·4	46·7	48·0	49·3	50·6
11	41·1	42·8	44·1	45·4	46·7	48·0
12	39·5	41·2	42·6	44·0	45·4	46·8
13	37·1	38·7	40·1	41·5	42·9	44·1
14	35·0	36·7	38·1	39·5	40·9	42·3
15	33·6	35·3	36·7	38·1	39·5	40·9
16	31·9	33·6	35·1	36·6	38·1	39·6
17	30·5	32·2	33·7	35·2	36·7	38·2
18	29·0	30·7	32·3	33·7	35·3	36·7
19	27·6	29·3	30·7	32·3	33·7	35·3
20	26·2	27·9	29·5	31·1	32·7	34·3

TABLE XLIV

70 cm.			**Focal-surface distance**			70 cm.
ED	15%	16%	17%	18%	19%	20%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	82·0	82·7	83·4	84·0	84·7	85·4
2	70·3	71·2	72·2	73·1	74·1	75·0
3	61·4	62·6	63·7	64·9	66·0	67·2
4	53·6	54·9	56·2	57·6	58·9	60·2
5	46·6	48·0	49·5	50·9	52·4	53·8
6	41·2	42·7	44·3	45·8	47·3	48·8
7	35·7	37·3	38·9	40·5	42·1	43·7
8	32·0	33·6	35·3	36·9	38·6	40·2
9	28·0	29·7	31·4	33·0	34·7	36·4
10	24·6	26·3	28·0	29·7	31·4	33·1
11	21·6	23·3	25·0	26·8	28·5	30·2
12	19·3	21·0	22·7	24·5	26·2	27·9
13	17·0	18·7	20·5	22·2	23·9	25·6
14	15·4	17·1	18·9	20·6	22·4	24·1
15	13·8	15·5	17·3	19·0	20·8	22·5
16	12·2	13·9	15·7	17·4	19·2	20·9
17	10·5	12·2	14·0	15·7	17·5	19·2
18	9·0	10·7	12·5	14·2	16·0	17·7
19	7·4	9·1	10·9	12·6	14·4	16·1
20	6·0	7·7	9·5	11·2	13·0	14·7

TABLE XLV

70 cm.	Focal-surface distance					70 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	86·1	86·7	87·4	88·1	89·8	91·5
2	76·0	76·9	77·9	78·8	79·8	80·7
3	68·4	69·5	70·9	71·8	73·0	74·2
4	61·5	62·8	64·2	65·5	66·8	68·1
5	55·3	56·7	58·2	59·6	61·1	62·5
6	50·4	51·9	53·4	55·0	56·5	58·0
7	45·3	46·9	48·5	50·1	51·7	53·3
8	41·8	43·5	45·1	46·8	48·4	50·0
9	38·1	39·8	41·4	43·1	44·8	46·5
10	34·8	36·5	38·2	39·9	41·6	43·3
11	31·9	33·6	35·4	37·1	38·8	40·5
12	29·7	31·4	33·1	34·9	36·6	38·3
13	27·4	29·1	30·8	32·6	34·3	35·0
14	25·8	27·6	29·3	31·1	33·8	34·5
15	24·3	26·0	27·8	29·5	31·3	33·0
16	22·7	24·4	26·2	27·9	29·7	31·4
17	21·0	22·7	24·5	26·2	28·0	29·7
18	19·5	21·2	23·0	24·7	26·5	28·2
19	17·9	19·6	21·4	23·1	24·9	26·6
20	16·5	18·2	20·0	21·7	23·5	25·2

TABLE XLVI

70 cm.	**Focal-surface distance**					70 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	92·0	92·6	93·2	93·8	94·2	94·8
2	81·7	82·6	83·2	83·8	84·4	85·0
3	75·3	76·5	77·4	78·3	79·2	80·1
4	69·4	70·8	71·8	72·8	73·8	74·8
5	64·0	65·4	66·5	67·6	68·7	69·8
6	59·6	61·1	62·2	63·3	64·4	65·5
7	54·9	56·5	57·7	58·9	60·1	61·3
8	51·7	52·3	53·5	54·7	55·9	57·1
9	48·2	49·8	51·0	52·2	53·4	54·6
10	45·0	46·7	48·0	49·3	50·6	51·9
11	42·2	44·0	45·3	46·6	47·9	49·1
12	40·1	41·8	43·2	44·6	46·0	47·4
13	36·7	38·5	39·9	41·3	42·7	43·1
14	36·0	37·2	38·2	39·6	41·0	42·5
15	34·8	36·5	37·9	39·2	40·4	41·5
16	33·2	34·7	36·2	37·7	39·2	40·5
17	31·5	33·2	34·7	36·1	37·6	39·1
18	30·0	31·7	32·2	33·7	35·2	36·9
19	28·4	30·1	31·7	32·3	33·5	35·4
20	27·0	28·7	30·2	31·8	32·9	34·5

TABLE XLVII

75 cm.	Focal-surface distance					75 cm.
ED	15%	16%	17%	18%	19%	20%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	82·0	82·7	83·4	84·1	84·8	85·4
2	70·3	71·2	72·2	73·1	74·1	75·5
3	61·4	62·6	63·8	65·0	66·2	67·3
4	53·6	54·8	56·1	57·3	58·6	59·8
5	46·3	47·7	49·0	50·4	51·8	53·1
6	41·3	42·9	44·4	46·0	47·6	49·1
7	36·5	38·1	39·8	41·4	43·1	44·7
8	32·5	34·2	35·9	37·6	39·3	40·9
9	28·4	30·1	31·8	33·6	35·3	37·0
10	25·0	26·7	28·5	30·2	32·0	33·7
11	21·7	23·5	25·2	27·0	28·7	30·5
12	19·9	21·7	23·4	25·2	26·9	28·7
13	17·5	19·3	21·0	22·8	24·5	26·3
14	15·6	17·4	19·1	20·9	22·7	24·4
15	13·8	15·6	17·3	19·1	20·9	22·6
16	12·1	13·8	15·6	17·4	19·2	20·9
17	10·6	12·4	14·1	15·9	17·7	19·4
18	9·1	10·9	12·6	14·4	16·2	18·0
19	7·7	9·5	11·3	13·0	14·8	16·6
20	6·2	8·0	9·7	11·5	13·3	15·1

TABLE XLVIII

75 cm.			Focal-surface distance			75 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	86·1	86·8	87·5	88·2	88·9	89·6
2	76·0	76·9	77·9	78·8	79·8	80·7
3	68·5	69·7	70·9	72·1	73·3	74·5
4	61·1	62·3	63·6	64·8	66·1	67·3
5	54·5	55·9	57·3	58·6	60·0	61·4
6	50·7	52·3	53·9	55·4	57·0	58·6
7	46·3	48·0	49·6	51·3	52·9	54·5
8	42·6	44·3	46·0	47·7	49·4	51·1
9	38·7	40·4	42·2	43·9	45·6	47·5
10	35·5	37·2	39·0	40·7	42·5	44·2
11	32·3	34·0	35·8	37·5	39·3	41·1
12	30·5	32·2	34·0	35·7	37·5	39·3
13	28·1	29·8	31·6	33·3	35·1	38·8
14	26·2	28·0	29·8	31·5	33·3	35·1
15	24·4	26·2	28·0	29·7	31·5	33·3
16	22·7	24·5	26·3	28·0	29·8	31·6
17	21·2	23·8	24·8	26·5	28·3	30·1
18	19·8	21·6	23·3	25·1	26·9	28·7
19	18·4	20·2	21·9	23·7	25·5	27·3
20	16·9	18·7	20·4	22·2	24·0	25·8

TABLE XLIX

75 cm.	Focal-surface distance					75 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	90·3	90·9	91·5	92·1	93·7	94·3
2	81·7	82·6	83·2	83·8	84·4	85·0
3	75·7	76·9	77·7	78·6	79·5	80·4
4	68·6	69·8	70·8	71·8	72·8	73·8
5	62·7	64·1	65·2	66·3	67·4	68·5
6	60·1	61·7	62·8	63·9	65·0	66·1
7	56·2	57·8	59·0	60·2	61·4	62·6
8	52·8	54·5	55·6	56·8	58·0	59·2
9	49·0	50·7	51·9	53·1	54·3	55·7
10	46·0	47·7	49·0	50·3	51·6	52·9
11	42·8	44·6	45·8	47·1	48·4	49·7
12	41·0	42·8	44·2	45·6	47·0	48·4
13	38·6	40·4	41·8	43·2	44·6	46·0
14	36·8	38·6	39·8	41·0	42·2	43·4
15	35·4	36·8	38·2	39·6	41·6	42·4
16	33·3	35·1	36·6	38·2	39·8	41·2
17	31·8	33·6	35·1	36·6	38·2	39·8
18	30·5	32·2	33·8	35·2	36·8	38·2
19	29·0	30·8	32·4	34·0	35·6	37·2
20	27·6	29·3	30·7	32·3	33·9	35·5

TABLE L

80 cm.			**Focal-surface distance**			80 cm.
ED	15%	16%	17%	18%	19%	20%
d	PD	PD	PD	PD	PD	PD
0	% 100	% 100	% 100	% 100	% 100	% 100
1	82·8	83·5	84·2	84·9	85·6	86·3
2	71·0	72·0	73·0	74·0	75·0	76·0
3	61·4	62·6	63·8	65·1	66·3	67·5
4	53·7	55·1	56·4	57·8	59·2	60·5
5	47·1	48·6	50·1	51·6	53·1	54·6
6	41·8	43·4	44·9	46·5	48·1	49·7
7	37·8	39·4	41·1	42·7	44·4	46·0
8	33·1	34·8	36·5	38·1	39·8	41·4
9	29·0	30·7	32·5	34·1	35·9	37·6
10	25·3	27·1	28·8	30·6	32·4	34·1
11	22·3	24·1	25·9	27·6	29·4	31·2
12	19·9	21·7	23·5	25·2	27·0	28·8
13	17·8	19·6	21·4	23·1	24·9	26·7
14	15·8	17·6	19·4	21·1	22·9	24·7
15	14·0	15·8	17·6	19·4	21·2	22·9
16	12·4	14·2	16·0	17·8	19·6	21·3
17	10·9	12·7	14·5	16·3	18·0	19·8
18	9·2	11·0	12·8	14·6	16·4	18·2
19	7·8	9·6	11·4	13·2	15·0	16·8
20	6·4	8·2	10·0	11·8	13·6	15·4

TABLE LI

80 cm.			Focal-surface distance			80 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	88·0	88·7	89·4	90·1	90·8	91·5
2	77·0	79·0	80·0	81·0	82·0	83·0
3	68·7	69·9	71·2	72·4	73·6	74·8
4	61·9	63·3	64·6	66·0	67·4	68·8
5	56·1	57·6	59·1	60·6	62·1	63·6
6	51·3	52·8	54·4	56·0	57·6	59·2
7	47·6	49·3	50·9	52·6	54·2	55·8
8	43·1	44·8	46·5	48·1	49·8	51·4
9	39·2	41·0	42·7	44·4	46·1	47·8
10	35·9	37·7	39·5	41·2	43·0	44·7
11	33·0	34·8	36·5	38·3	40·1	41·9
12	30·6	32·4	34·1	35·9	37·7	39·5
13	28·5	30·2	32·0	33·8	35·6	37·4
14	26·5	28·3	30·0	31·8	33·6	35·4
15	24·7	26·5	28·3	30·1	31·9	33·7
16	23·1	24·9	26·7	28·5	30·3	32·0
17	21·6	23·4	25·2	27·0	28·8	30·6
18	20·0	21·8	23·6	25·4	27·2	29·0
19	18·6	20·4	22·2	24·0	25·8	27·6
20	17·2	19·0	20·8	22·6	24·4	26·2

TABLE LII

80 cm.			Focal-surface distance			80 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
0	% 100	% 100	% 100	% 100	% 100	% 100
1	91·9	92·3	92·9	93·5	94·1	94·7
2	83·0	84·0	84·8	85·6	86·4	87·2
3	76·0	77·2	78·1	79·0	79·9	80·8
4	70·1	71·5	72·5	73·5	74·5	75·5
5	65·1	66·6	67·7	68·8	69·9	71·0
6	60·8	62·3	63·4	64·5	66·7	67·8
7	57·5	59·1	60·3	61·5	62·7	63·9
8	53·1	54·8	56·0	57·2	58·4	59·6
9	49·5	51·3	52·5	53·7	54·9	56·1
10	46·5	48·3	49·6	50·9	52·2	53·5
11	43·6	45·4	46·7	48·0	49·3	50·6
12	41·3	43·0	44·4	45·8	47·2	48·6
13	39·1	40·9	41·3	42·7	44·3	45·7
14	37·2	38·9	39·3	40·7	42·0	43·7
15	35·5	37·2	38·6	40·0	41·4	42·8
16	33·8	35·6	37·1	38·6	40·1	41·6
17	32·4	34·1	35·6	37·1	38·6	40·1
18	30·8	32·6	33·2	34·8	36·4	38·0
19	29·4	31·2	32·8	33·2	34·8	36·4
20	28·0	29·8	31·4	33·0	34·4	35·8

TABLE LIII

85 cm.			Focal-surface distance			85 cm.
ED	15%	16%	17%	18%	19%	20%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	83·2	83·9	84·6	85·4	86·1	86·8
2	71·8	72·8	73·8	74·9	75·9	77·0
3	62·7	63·9	65·2	66·4	67·7	68·9
4	54·3	55·7	57·1	58·4	59·8	61·2
5	47·7	49·2	50·7	52·3	53·8	55·3
6	42·2	43·8	45·4	47·0	48·6	50·2
7	37·4	39·1	40·7	42·4	44·1	45·7
8	33·2	34·9	36·6	38·4	40·1	41·8
9	29·1	30·8	32·6	34·3	36·1	37·8
10	25·6	27·4	29·2	30·9	32·7	34·5
11	22·6	24·4	26·2	28·0	29·8	31·6
12	20·1	21·9	23·7	25·5	27·3	29·1
13	18·0	19·8	21·6	23·4	25·2	27·0
14	16·1	17·9	19·7	21·5	23·3	25·1
15	14·4	16·2	18·0	19·8	21·6	23·4
16	12·6	14·4	16·2	18·0	19·9	21·7
17	11·0	12·8	14·6	16·5	18·3	20·1
18	9·4	11·2	13·0	14·7	16·7	18·5
19	8·0	9·8	11·6	13·5	15·3	17·1
20	6·6	8·3	10·2	12·0	13·9	15·7

TABLE LIV

85 cm.	Focal-surface distance					85 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	87·5	88·2	88·9	89·6	90·4	91·1
2	78·6	79·1	80·1	81·1	82·2	83·2
3	70·1	71·4	72·6	73·8	75·1	76·3
4	62·6	64·0	65·3	66·7	68·1	69·5
5	56·8	58·3	59·9	61·4	62·9	64·4
6	51·8	53·4	55·0	56·6	58·2	59·8
7	47·4	49·1	50·8	52·4	54·1	55·8
8	43·5	45·2	47·0	48·7	50·4	52·1
9	39·6	41·3	43·1	44·8	46·6	48·3
10	36·3	38·1	39·8	41·6	43·4	45·2
11	33·4	35·2	37·0	38·8	40·6	42·4
12	31·0	32·8	34·6	36·4	38·2	40·0
13	28·9	30·7	32·5	34·3	36·1	37·9
14	27·0	28·8	30·6	32·4	34·2	36·0
15	25·3	27·1	28·9	30·7	32·5	34·3
16	23·5	25·3	27·2	29·0	30·8	32·6
17	21·9	23·7	25·5	27·4	29·2	31·0
18	20·3	22·2	24·0	25·8	27·6	29·4
19	18·9	20·7	22·5	24·4	26·2	28·0
20	17·5	19·3	21·1	23·0	24·8	26·6

TABLE LV

85 cm.			**Focal-surface distance**			85 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	92·0	92·5	93·1	93·7	94·3	94·9
2	84·3	85·3	86·1	86·9	87·7	88·5
3	77·6	78·8	79·7	80·6	81·5	82·4
4	70·9	72·2	73·2	74·2	75·2	76·2
5	65·9	67·4	68·5	69·6	70·7	71·8
6	61·4	63·0	64·1	65·2	66·3	67·4
7	57·4	59·1	60·3	61·5	62·7	63·9
8	53·8	55·5	56·7	57·9	59·1	60·3
9	50·1	51·8	53·0	54·2	55·4	56·6
10	46·9	48·7	50·0	51·3	52·6	53·9
11	44·2	46·0	47·3	48·6	49·9	51·2
12	41·8	43·6	45·4	46·8	48·2	49·6
13	39·7	41·5	42·9	44·3	45·7	47·1
14	37·8	39·6	41·0	42·4	43·8	45·2
15	36·1	37·9	39·3	40·7	42·3	43·7
16	34·4	36·2	37·7	39·2	40·7	42·2
17	32·8	34·5	36·0	37·5	39·0	40·5
18	31·2	33·1	34·7	36·2	37·7	39·3
19	29·8	31·4	33·0	34·6	36·2	37·8
20	28·4	30·2	31·8	33·4	35·0	36·6

TABLE LVI

90 cm.	Focal-surface distance					90 cm.
ED	15%	16%	17%	18%	19%	20%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	83·3	83·9	84·7	85·4	86·2	86·9
2	71·8	72·8	73·9	75·0	76·0	77·1
3	62·7	63·9	65·2	66·5	67·7	69·0
4	54·3	55·7	57·1	58·6	60·0	61·4
5	47·7	49·2	50·8	52·3	53·9	55·4
6	42·2	43·8	45·5	47·1	48·8	50·4
7	37·4	39·1	40·8	42·5	44·2	45·9
8	33·2	34·9	36·7	38·4	40·2	41·9
9	29·1	30·9	32·6	34·4	36·2	38·0
10	25·9	27·7	29·5	31·3	33·1	34·9
11	22·1	23·9	25·7	27·5	29·3	31·1
12	20·2	21·9	23·7	25·6	27·4	29·7
13	18·2	20·0	21·8	23·5	25·3	27·1
14	16·5	18·3	20·2	21·9	23·8	25·6
15	14·6	16·4	18·3	20·1	21·9	23·7
16	13·0	14·8	16·7	18·5	20·3	22·1
17	11·4	13·2	15·1	16·9	18·7	20·5
18	9·5	11·3	13·2	15·0	16·8	18·7
19	8·2	10·0	11·9	13·7	15·6	17·4
20	6·7	8·5	10·4	12·2	14·0	15·9

TABLE LVII

90 cm.	Focal-surface distance					90 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	87·6	88·4	89·1	89·8	90·6	91·3
2	78·2	79·2	80·3	81·3	82·4	83·5
3	70·3	71·5	73·8	75·0	76·3	77·6
4	62·8	64·2	65·7	67·1	68·5	69·9
5	57·0	58·5	60·1	61·6	63·2	64·7
6	52·0	53·7	55·3	56·9	58·6	60·2
7	47·6	49·3	51·0	52·7	54·4	56·1
8	43·7	45·4	47·2	48·9	50·7	52·4
9	39·7	41·6	43·3	45·1	46·9	48·7
10	36·7	38·5	40·3	42·1	43·9	45·7
11	32·9	34·7	36·6	38·4	40·2	42·0
12	31·0	32·8	34·5	36·3	38·1	39·9
13	28·9	30·6	32·4	34·2	36·0	37·8
14	27·6	29·2	31·1	32·8	34·7	36·5
15	25·5	27·4	29·2	31·1	32·9	34·7
16	23·9	25·8	27·6	29·5	31·3	33·1
17	22·3	24·2	26·0	27·9	29·7	31·5
18	20·5	22·4	24·2	26·1	27·9	29·7
19	19·2	21·1	22·9	24·8	26·6	28·4
20	17·7	19·6	21·4	23·3	25·1	26·9

TABLE LVIII

90 cm.			**Focal-surface distance**			90 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
0	% 100	% 100	% 100	% 100	% 100	% 100
1	92·1	92·5	92·9	93·4	94·0	94·6
2	84·5	85·6	86·4	87·2	88·0	88·8
3	78·8	80·1	81·0	82·9	83·8	84·7
4	71·3	72·7	73·8	74·8	75·8	76·8
5	66·3	67·8	68·9	70·0	71·1	72·2
6	61·9	63·5	64·6	65·7	66·8	67·9
7	57·8	59·5	60·7	61·9	63·1	64·3
8	54·2	55·9	57·1	58·3	59·5	60·7
9	50·5	52·2	53·4	54·6	55·8	57·0
10	47·5	49·3	50·6	51·9	53·2	54·5
11	44·8	46·6	47·9	49·2	50·5	51·8
12	41·6	43·4	44·8	46·2	47·6	49·0
13	39·7	41·5	42·9	44·1	45·5	46·9
14	38·3	40·1	41·5	42·9	44·3	45·7
15	36·6	38·3	39·7	41·1	42·5	43·9
16	34·9	36·8	38·3	39·8	41·3	42·8
17	33·4	35·2	36·7	38·2	39·7	41·2
18	31·6	33·4	35·0	36·6	38·2	39·8
19	30·3	32·1	33·7	35·3	36·9	38·5
20	28·8	30·6	32·2	33·8	35·4	37·0

TABLE LIX

95 cm.	**Focal-surface distance**					95 cm.
ED	15%	16%	17%	18%	19%	20%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	82·7	83·4	84·2	84·9	85·7	86·4
2	72·5	73·6	74·6	75·7	76·8	77·8
3	61·4	62·3	63·9	65·2	66·5	67·8
4	55·5	56·9	58·4	59·8	61·3	62·7
5	48·2	49·8	51·3	52·9	54·5	56·0
6	42·2	43·9	45·5	47·2	48·8	50·5
7	37·8	39·5	41·2	42·9	44·7	46·4
8	33·6	35·4	38·1	39·9	41·7	43·4
9	29·5	31·3	33·1	34·9	36·7	38·5
10	26·2	28·0	29·8	31·7	33·5	35·3
11	23·2	25·0	26·8	28·7	30·5	32·3
12	20·7	22·5	24·4	26·2	28·0	29·8
13	18·5	20·3	22·2	24·0	25·9	27·7
14	16·3	18·1	20·0	21·8	23·7	25·5
15	15·0	16·8	18·7	20·5	22·4	24·2
16	13·1	14·9	16·8	18·6	20·5	22·3
17	11·5	13·3	15·2	17·0	18·9	20·7
18	9·5	11·3	13·2	15·0	16·9	18·7
19	8·2	10·0	11·9	13·7	15·6	17·4
20	6·7	8·5	10·4	12·2	14·1	15·9

TABLE LX

95 cm.			**Focal-surface distance**			95 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
0	% 100	% 100	% 100	% 100	% 100	% 100
1	87·2	87·9	88·7	89·4	90·2	90·9
2	78·9	80·0	81·1	82·1	83·2	84·3
3	69·1	70·3	71·6	72·9	74·2	75·4
4	64·1	65·6	67·0	68·5	69·9	71·4
5	57·6	59·2	60·7	62·3	63·9	65·5
6	52·1	53·8	55·5	57·1	58·8	60·5
7	48·1	49·8	51·5	53·3	55·0	56·7
8	45·2	47·0	48·8	50·5	52·3	54·1
9	40·3	42·1	43·9	45·7	47·5	49·3
10	37·1	38·9	40·7	42·6	44·4	46·2
11	34·2	36·0	37·8	39·7	41·5	43·3
12	31·7	33·5	35·3	37·2	39·0	40·8
13	29·5	31·4	33·2	35·0	36·9	38·7
14	27·3	29·2	31·0	32·9	34·7	36·5
15	26·6	27·9	29·7	31·6	33·4	35·2
16	24·2	26·0	27·9	29·7	31·6	33·4
17	22·6	24·4	26·3	28·1	30·0	31·8
18	20·6	22·4	24·3	26·1	28·0	29·8
19	19·3	21·1	23·0	24·8	26·7	28·5
20	17·8	19·6	21·5	23·9	25·2	27·0

TABLE LXI

95 cm.			Focal-surface distance			95 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	91·8	92·7	93·4	94·0	94·6	95·2
2	85·3	86·4	87·2	88·0	88·8	89·6
3	77·7	79·0	79·9	80·8	81·7	82·6
4	72·8	74·2	75·3	76·3	77·3	78·3
5	67·0	68·6	69·7	70·8	71·9	73·0
6	62·1	63·8	64·9	66·0	67·1	68·2
7	58·4	60·2	61·4	62·6	63·8	65·0
8	55·8	57·7	58·9	60·1	61·3	62·5
9	51·1	52·9	54·1	55·3	57·5	58·7
10	48·0	49·9	51·2	52·5	53·8	55·1
11	45·2	47·0	48·3	49·6	50·9	52·2
12	42·7	44·5	45·9	47·3	48·7	50·1
13	40·6	42·4	43·8	45·2	46·6	48·0
14	38·4	40·2	41·6	43·0	44·4	45·8
15	37·1	38·9	40·3	41·7	43·1	44·5
16	35·3	37·1	38·6	40·1	41·6	43·1
17	33·7	35·5	37·0	38·5	40·0	41·5
18	31·7	33·5	35·1	36·6	38·2	39·8
19	30·4	32·2	33·8	35·4	37·0	38·6
20	28·9	30·7	32·3	33·9	35·5	37·1

TABLE LXII

100 cm.			**Focal-surface distance**			100 cm.
ED	15%	16%	17%	18%	19%	20%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	82·7	83·5	84·3	85·0	85·8	86·6
2	72·5	73·6	74·7	75·8	76·9	77·9
3	64·0	65·3	66·6	67·9	69·2	70·5
4	56·0	58·1	59·5	61·0	62·5	64·0
5	49·3	50·9	52·5	54·1	55·7	57·3
6	43·2	44·9	46·6	48·3	50·0	51·7
7	38·3	40·0	41·8	43·5	45·3	47·0
8	34·0	35·8	37·6	39·3	41·1	42·8
9	29·2	31·6	33·4	35·3	37·1	38·9
10	26·2	28·0	29·9	31·7	33·6	35·4
11	23·5	25·3	27·2	28·0	29·9	31·7
12	21·2	23·1	24·9	26·8	28·6	30·5
13	18·5	20·4	22·2	24·1	25·9	27·8
14	16·9	18·8	20·6	22·5	24·3	26·2
15	15·2	17·1	18·9	20·8	22·6	24·5
16	13·3	15·2	17·0	18·9	20·8	22·6
17	11·7	13·6	15·4	17·3	19·2	21·0
18	10·1	12·0	13·8	15·7	17·6	19·5
19	8·6	10·5	12·3	14·2	16·1	18·0
20	7·2	9·1	11·0	12·8	14·7	16·6

TABLE LXIII

100 cm.		**Focal-surface distance**				100 cm.
ED	21%	22%	23%	24%	25%	26%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	87·4	88·1	88·9	89·7	90·5	91·2
2	79·0	80·1	81·2	82·3	83·4	84·5
3	71·8	73·1	74·4	75·7	77·0	78·3
4	65·5	66·9	68·4	69·9	71·4	72·9
5	58·9	60·5	62·1	63·7	65·3	69·9
6	53·4	55·1	56·8	58·5	60·2	61·9
7	48·7	50·5	52·2	54·0	55·7	57·4
8	44·6	46·3	48·1	49·9	51·7	53·4
9	40·7	42·5	44·3	46·2	48·0	49·8
10	37·2	39·1	40·9	42·7	44·6	46·4
11	33·6	35·4	37·3	39·1	41·0	42·8
12	32·4	34·2	36·1	37·9	39·8	41·7
13	29·6	31·5	33·4	35·2	37·1	39·0
14	28·0	29·9	31·8	33·6	35·5	37·4
15	26·3	28·2	30·1	31·9	33·8	35·6
16	24·5	26·4	28·3	30·1	32·0	33·9
17	22·9	24·8	26·7	28·5	30·4	32·3
18	21·4	23·3	25·1	27·0	28·9	30·8
19	19·9	21·7	23·6	25·5	27·4	29·3
20	18·5	20·3	22·2	24·1	26·0	27·9

TABLE LXIV

100 cm.			Focal-surface distance			100 cm.
ED	27%	28%	29%	30%	31%	32%
d	PD	PD	PD	PD	PD	PD
	%	%	%	%	%	%
0	100	100	100	100	100	100
1	92·1	92·8	93·5	94·1	94·7	95·3
2	85·6	86·7	87·3	88·1	88·9	89·7
3	79·6	80·9	81·8	82·7	83·6	84·5
4	74·4	75·8	76·8	77·8	78·8	79·8
5	68·5	69·3	70·2	71·3	72·4	73·5
6	63·6	65·3	66·4	67·5	68·6	69·7
7	59·2	61·9	63·1	64·3	65·5	66·7
8	55·2	57·0	58·2	59·4	60·6	61·8
9	51·6	53·5	54·7	55·9	57·1	58·3
10	48·3	49·4	50·7	52·0	53·3	54·6
11	44·7	46·5	47·8	49·1	50·4	51·7
12	43·5	45·4	46·8	48·2	49·6	51·0
13	40·8	42·6	44·0	45·4	47·0	48·4
14	39·2	41·1	42·5	43·9	45·3	46·7
15	37·5	39·4	40·8	42·2	43·6	45·0
16	35·7	37·6	39·1	40·6	42·2	43·7
17	34·1	36·0	37·5	39·0	40·5	42·0
18	32·6	34·5	36·1	37·7	39·3	40·9
19	31·1	33·0	34·6	36·2	37·8	39·4
20	29·7	31·6	33·2	34·8	36·4	38·0

b. Instruction for the use of Table LXV.

The following Table, LXV, supplies the calculation of practical doses at all depths when the field of incidence is greater than 150 sq. cm., as it is when long distance applications are used. The procedure is as follows: The practical dose, P.D., for the field of incidence F of 150 sq. cm. at the required focal-surface distance is calculated with the aid of one of the Tables XVII–LXIV. Suppose that it is 50% at a depth of 6 cm. The field of incidence F to be used, we will suppose, is 300 cm. The factor m for the field of incidence $F = 300$ sq. cm. is then turned up in Table LXV. Search is then made for the factor n corresponding to the depth of 6 cm., which is also given in Table LXV. The practical dose in this case is therefore

$$\text{P.D.} = \text{P.D.} \times m \times n. \qquad (55)$$

or, by substitution,

$$\begin{aligned}\text{P.D.} &= 50\% \times 1{\cdot}139 \times 1{\cdot}022 \qquad (56)\\ &= 58{\cdot}2\%,\end{aligned}$$

when P.D. is the practical dose calculated for the field of incidence $F = 150$ sq. cm.

TABLE LXV

d		0–1	2–3	4–6	7–9	10–15	16–20
F	**m**	**n**	**n**	**n**	**n**	**n**	**n**
150	1·000	1·000	1·000	1·000	1·000	1·000	1·000
160	1·018	1·000	1·002	1·004	1·006	1·009	1·013
170	1·035	1·000	1·005	1·007	1·009	1·012	1·016
180	1·043	1·000	1·007	1·009	1·011	1·014	1·018
190	1·053	1·000	1·009	1·011	1·013	1·016	1·020
200	1·064	1·000	1·010	1·013	1·015	1·018	1·022
220	1·089	1·000	1·012	1·014	1·016	1·019	1·023
240	1·107	1·000	1·014	1·016	1·018	1·021	1·025
260	1·125	1·000	1·016	1·018	1·020	1·023	1·027
280	1·128	1·000	1·018	1·020	1·022	1·025	1·029
290	1·131	1·000	1·019	1·021	1·023	1·026	1·030
300	1·139	1·000	1·020	1·022	1·024	1·027	1·031
320	1·145	1·000	1·021	1·023	1·025	1·028	1·032
340	1·148	1·000	1·022	1·024	1·026	1·029	1·033
360	1·151	1·000	1·023	1·025	1·027	1·030	1·034
380	1·155	1·000	1·024	1·027	1·028	1·031	1·035
400	1·160	1·000	1·025	1·028	1·029	1·032	1·036

VI

THE CALIBRATION OF X-RAY APPARATUS AND X-RAY TUBES

THE surface dose received by a patient during an irradiation may be measured either directly or indirectly.

The direct method is to ascertain actually on the patient, by means of an instrument calibrated to measure in given units (*R* units), when the required dose has been reached. The indirect method is to calibrate X-ray apparatus and X-ray tubes at given intervals of time by the use of an accurate measuring instrument, which can be set to measure in given units (*R* units), and to irradiate by time alone. It has been urged against this indirect method that X-ray apparatus and tubes do not always work with uniform efficiency and may manifest great variations in their output of radiations, so that dosage by time is unreliable. Nowadays, however, X-ray apparatus and tubes have reached such a state of technical perfection, and are so constant in their working, that dosage by time is in fact absolutely trustworthy. Moreover, irradiation by time is preferable to the direct method because the assistant staff can confine their attention to the apparatus and tube, instead of having to devote a certain amount of it to the calibrated measuring-instrument. The method of irradiation by time will be discussed in some detail, partly because it forms the basis of the dosage tables, and partly because it can be carried out with their help.

The conditions for time-dosage are:

i. Calibration of the apparatus to be used.

ii. Calibration of the tube.

These ensure that the mixture of radiations emitted from an X-ray tube under given electrical conditions is tested both for quality and quantity by a suitable measuring instrument, such as those described in Chapter VI, and that the electrical conditions under which they are generated are properly known. Since the X-ray tube is now supposed to operate constantly over long periods of time, and in fact does so under modern technical conditions, the electrical conditions are ascertained, and then work is carried on for several days by the clock alone, i.e. dosage is estimated entirely by time, the same electrical conditions being reproduced at each application. The different depths and distances of the organs to be irradiated are taken into account with the aid of these tables, according to the instructions given. At certain intervals the radiations are checked with the same instruments that are used for calibration, and any changes that have occurred are ascertained. The primary consideration in this method of dosage by time is therefore the calibration of the X-ray apparatus and tubes; in other words, it is necessary in time-dosage to reproduce exactly at every application all the electrical factors which determine the character of a mixed bundle of X-rays. The composition of the mixture of rays emitted by a tube depends for quality upon the effective X-ray voltage, and the quantity in the bundle depends upon the amount of the current that passes through the tube. Since the secondary voltage and the strength of the secondary current, when the tube is constant, also vary with the state of the primary circuit, the following electrical factors must be taken into account in the calibration of X-ray apparatus and tubes:

i. The potential of the main supply.
ii. The potential of the primary of the induction-coil, or, when a transformer is being used, the potential of the primary of the transformer.
iii. The strength of the primary current.
iv. The frequency at which the interrupter-motor is working, if one is used.
v. The potential on the tube.
vi. The strength of the secondary current.

When time dosage is employed it is absolutely necessary that all these factors in the performance of the tube should be constantly under control.

The calibration of apparatus and tubes can, of course, only be executed in a uniform manner when irradiation is carried out under fixed and unvarying conditions. In other words, **Dosage by time is only permissible when all the conditions of work can be continually checked. Failure to control these factors shows a complete lack of appreciation of the whole principle of calibrating X-ray apparatus and tubes.**

The calibration of X-ray apparatus and tubes falls into two divisions:

i. Biological calibration.
ii. Physical and technical calibration.

1. Biological Calibration.

The biological calibration of X-ray apparatus and tubes can be effected in two ways:

a. The skin unit dose, S.U.D., is ascertained quite empirically for a given mixture of rays for the production of which the conditions are known. When doing this it is always advisable to follow the recommendations of large clinics where tubes and apparatus of the same type are employed; but filtering, focal-surface distance, and other factors must be kept constant. When the operator has discovered the time taken to reach the skin unit dose, S.U.D., with a given tube, a standard one held in readiness for this purpose, under given working conditions, and has corrected this time by control measurements taken on the patient, he may proceed to carry out physical and technical calibration by means of accurate methods of measurement.

b. The operator ascertains, by means of an instrument calibrated in *R* units (such as Küstner's standard apparatus or Hammer's dosimeter), the time within which a given number of *R* units is delivered under properly stabilized conditions. To ascertain how many *R* units are necessary to reach the unit skin dose, he should in each particular case use the results published by the large clinics, for there is still a great deal of variation in the number of *R* units which has been found to produce a skin unit dose. The number given by most clinics at the present time is 600 *R*. Having ascertained from these experiments the time taken to reach the unit skin dose, and having checked it by control measurements on the patient, he may proceed to carry out physical and technical calibration as before.

2. Physical and Technical Calibration.

The operator measures the physical conditions by one of the methods described in Chapter IV, preferably by the use of an iontometric apparatus, employing the same tube that was used for the biological calibration under the same electrical working conditions. He then calibrates all the other tubes under the same conditions and establishes from these results the different times of irradiation required with tubes of different type. The times required differ according to the intensity of the emissions of each tube in use. The tubes employed must be broken in before they are used for irradiation, under electrical conditions identical with those under which the biological calibration was carried out. Each tube is worked in until its output becomes constant. Under no circumstances must a patient ever be irradiated with new and unseasoned tubes. Breaking-in, however, is unnecessary with tubes of the modern type, such as the Coolidge and Lilienfeld, since every condition of the tube can be produced at will and, moreover, maintained unaltered up to a certain limit.

When the tubes, meaning those of the gas-tube type, have been broken in, calibration may be commenced. The conditions of work chosen are, as has been stated, the same as those under which the biological calibration of the standard tube was carried out.

First of all the intensity of the rays is measured by an iontometric apparatus or, when this is not available, by a Fürstenau intensimeter or the Kienböck strips. If an iontometric apparatus is used, the operator measures the time taken by the pointer to return over a given number of divisions of the scale, or the extent of the deflection of the needle. It is advisable to repeat the measurements several times and extract the arithmetic mean. The values thus obtained are the measure of the intensity of the radiations emitted by the tube in use, and form the basis for calculating the time required by that particular tube to produce the skin unit dose. If Kienböck strips are used, the operator irradiates two strips with each tube and develops all the strips together at the end of the irradiations. The strips are fixed, washed and dried, pasted on to cardboard, and marked with numbers corresponding to the tubes to be calibrated and with the calibration data. The values obtained by this method are then compared with those obtained with the standard tube which was used to carry out the biological calibration, and differences are noted. When a picture has been obtained in this manner of the quantitative output of the tubes to be calibrated, compared with that of the standard tube, they are calibrated qualitatively by estimating the percentage deep dose, which is the basis for the use of the tables given in this volume.

Having ascertained the factors necessary for estimating dosage by time, it is possible, by comparing the values obtained with those of the standard tube, to estimate the time taken by each tube to deliver the skin unit dose and also the number of applications needed to administer the desired dose to the organ requiring treatment. Since, however, the performance of a tube does not remain constant over very long periods, the tubes should be tested at intervals and the times of irradiation corrected accordingly.

For exact time-dosage it is necessary, as has already been remarked, that the electrical working conditions shall be constant, and these conditions must be accurately reproduceable at each irradiation, if failures and injuries are to be avoided. We have already seen that the electrical factors which must be reproduced each time to ensure accurate time-dosage are:

i. The potential of the main supply.
ii. The potential of the primary of the induction-coil, or, when a transformer is being used, the potential of the primary of the transformer.
iii. The strength of the primary current.
iv. The frequency at which the interrupter-motor is working, if one is being used.
v. The potential on the tube.
vi. The strength of the secondary current.

Constant control is essential, and time dosage can only be employed when it is possible to control these factors continually. Failure to control them introduces the risk of changes occurring unawares in the quality and quantity of the beam and causing harm to the patient. A number of measuring instruments are used to control the electrical factors, and of these may be briefly mentioned:

i. The voltmeter, which is used to control the potential of the main, and is shunted across the main leads.

ii. The kilovoltmeter or the hardness indicator; these control the potential of the induction coil in the primary circuit or the tension in the primary of the transformer. The tension-hardness indicator or the kilovoltmeter is shunted across the primary winding of the induction coil or transformer. They serve as principal means of control over tubes of identical pattern.

iii. The ampèremeter is inserted into the primary circuit and measures the strength of the primary current.

iv. The tachometer is used for measuring from time to time the revolutions of the interrupter-motor, if one is in use.

v. The parallel spark-gap, by which the effective tension of the tube may be checked. This control is already provided for by means of the tension-hardness indicator and the kilovoltmeter, since any change in primary transformer current causes a corresponding change in the secondary, and vice versa, by reason of the constant ratio that exists between the two windings of an electrical transformer. Nevertheless it is advisable to check the reading of the tension-hardness indicator or kilovoltmeter from time to time by the parallel spark-gap and to calibrate them by it.

vi. The milliampèremeter, which is included in the secondary circuit and measures the tube current.

For calibrating the tension-hardness indicator or kilovoltmeter by the parallel spark-gap, Table LXVI is subjoined. In this table

s signifies the length of the spark in centimetres, and
v the peak tension of the tube current in kilovolts.

The values in this table hold good for a spark-gap with electrodes consisting of spheres 50 mm. in diameter. They have been obtained from the author's own estimations and give a very neat and uniform curve, so that any spark-length value may be interpolated between those given in the table and its corresponding v read off by calculation from the values above and below.

TABLE LXVI

S	V	S	V
3	80·5	**17**	166·0
4	92·4	**18**	169·0
5	102·0	**19**	172·0
6	111·0	**20**	175·0
7	119·0	**21**	177·0
8	126·0	**22**	180·0
9	132·5	**23**	182·0
10	138·0	**24**	184·5
11	143·0	**25**	187·0
12	148·0	**26**	189·0
13	153·0	**27**	190·0
14	157·0	**28**	192·0
15	160·0	**29**	194·0
16	163·5	**30**	196·0

TABLE LXVII

λ_0	V	λ_0	V
0·06	207·0	0·14	88·6
0·07	177·0	0·15	82·7
0·08	155·0	0·16	77·5
0·09	138·0	0·17	73·0
0·10	124·0	0·18	68·9
0·11	112·7	0·19	65·3
0·12	103·5	0·20	62·0
0·13	95·4	0·21	59·0

Table LXVII enables the tension-hardness indicator or the kilovoltmeter to be calibrated when desired in terms of maximum wave-length. The maximum wave-length of the quenched rays (Bremsröntgenstrahlen) generated in a tube depends entirely upon the peak voltage of the tube current. It is calculated from the equation:

$$\lambda_0 \text{ in } \mathring{A}U = \frac{12{\cdot}35}{v} \quad . \quad . \quad . \quad . \quad . \quad (57)$$

when λ is the maximum wave-length and v is the peak voltage of the tube current.

When the electrical factors, as measured by the instruments described, are constant, and the tube has been broken in and calibrated, it may be assumed for purposes of calculation that the composition of the rays is constant both for quantity and quality.

A valuable aid to the control of the work is afforded by making out calibration charts, one for each tube, on which all the physical and technical factors are recorded in full detail. This chart should bear numbers corresponding with those of the tubes which have been calibrated. A similar chart should be made for the standard tube. When a tube is being taken into use, its chart should be brought out along with it, and irradiation should only be carried out under conditions which meticulously reproduce those recorded on the chart. The assistant staff should be ordered to report at once any change in these factors, and the radiologist in charge of the treatment has then to decide whether the irradiation can proceed, how much, if at all, to alter the time of exposure, or whether the irradiation must be completely discontinued until it is possible to reproduce the calibration on factors.

Simple alarm clocks are generally used for controlling the times of application, and the time when estimated is entered on the patient's chart. It is better not to rely upon a single clock, but to check it by another, so as to eliminate errors of exposure due to faults in the clock, a possible source of grave danger. It is extremely useful to double-check the alarm-clock readings with a so-called 'recording clock', a plan which I have myself instituted. These recording clocks[1] have chronometer works and provide not only an efficient control of the time of application but also a record for the patient's chart, since they record the time graphically on a strip of paper.

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[1] These clocks are supplied by the Michael Sendtner A.G., Fabrik für Präzisionsinstruments, Munich, Schillerstrasse 22.

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