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LEAGUE OF NATIONS

HEALTH ORGANISATION

PROTECTIVE MEASURES

against

DANGERS RESULTING FROM THE USE OF RADIUM, ROENTGEN AND ULTRA-VIOLET RAYS

BY

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WITH THE ASSISTANCE OF

Privatdozent Walther RUMP, Ph.D.

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PREFACE

During its twelfth session, the Health Committee had before it a memorandum prepared by Dr. Jitta, member of the Committee, and Dr. van der Plaats, radiologist at Utrecht, on the dangers that may be entailed by the use of X-rays.

In accordance with the Health Committee's recommendations, the Health administrations in various countries were invited to supply information on the regulations in force in this connection.

The Health Organisation secured the valuable services of an eminent radiologist, Dr. H. Wintz, Professor of Clinical Gynæcology at the University of Erlangen, who undertook to prepare the present report on the basis of the information thus collected. In drawing up the report, Professor Wintz was assisted by Privatdozent Walther Rump, Ph.D., who has special knowledge of the subject.

The Health Section appreciates the painstaking care with which the authors have done their work and desires to extend its most cordial thanks to them.

Health Section of the Secretariat
of the League of Nations.

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INTRODUCTION

The use of Roentgen, radium and ultra-violet rays in medicine is still in its infancy as a science; in a very short space of time, it has, however, acquired considerable importance. Outside the medical field, the technique of Roentgen and ultra-violet irradiation has also been turned to account in the examination of materials.

The practical uses of Roentgen, radium, and ultra-violet rays thus concern a very large section of the public, and, since both the rays emitted and the apparatus are attended by certain dangers, protective measures are necessary.

In the following pages, I shall first discuss the processes and conditions on which the protective measures are based. My observations will, however, need to be supplemented as time goes on, for a subject in so fluid a state of development cannot be adequately surveyed at any arbitrarily selected point of time.

That rays may prove dangerous to the human organism was established in the first days of experimental tests with Roentgen and radium rays. Through negligence or ignorance many research workers and doctors sustained injuries or even lost their lives.

Knowledge of the deleterious action of the rays does not, however, dispose of the problem of protection ; far from it. For effective protection from injury means, not only eliminating the damaging action of the rays, but also removing all the dangers that accompany the generating process and the whole of the work in this field.

The matter of this survey thus falls automatically under the following headings:

I. Protection from direct injury by rays.

II. Protection from the accidents that may be caused by the generating plant.

III. Protection from unhealthy conditions in working premises (hygienic measures).

IV. Protection from the dangers of fire or of gas poisoning in the event of X-ray films catching fire.

Regulations designed to provide against these dangers are in force in all countries. So far, hygienic measures have received least attention, but underestimation of their importance undoubtedly brings as many dangers in its train as the absorption of rays by the organism. In reading some of the regulations, it is indeed hard to resist the impression that the dangers of injury by direct exposure to radiation have undoubtedly been overestimated. Where health and life are at stake, regulations cannot, admittedly, be made too severe; it must, however, be borne in mind that such regulations restrict in some measure the scope of the work, thereby setting a limit to the beneficial action of the rays. The legislating authorities must therefore steer a middle course between this Scylla and Charybdis. For this very reason the whole problem is not as simple as it may perhaps appear to the onlooker.

Chapter I.

PROTECTION AGAINST THE DANGERS CAUSED BY RADIATION.

Protection measures are required :

A. Generally for persons who, for professional reasons, or owing to the special location of the premises in which they work, are in proximity to sources of short-wave radiation, that is to say :

1. The director of the establishment (the doctor);

2. The establishment staff operating the controls of the source of radiation (X-ray apparatus, quartz-mercury lamps, etc.); persons engaged in putting up radio-active substances into containers ;

3. Persons remaining in rooms in the vicinity of sources of radiation (X-ray establishments, radio-active substances).

B. In cases where short-wave radiation is applied to human beings (examination with X-rays and ultra-violet light, therapeutic treatment with X-rays with the radiation of radio-active substances, with ultra-violet light and with cathode rays).

A. Protective Measures for Persons remaining in Proximity to Sources of Short-Wave Rays.

In gauging the injurious effects of radiation on the human organism, reference may be had, by way of comparison, to the action of poisons. In toxicology the most important thing to know is what quantities are harmful and what quantities can certainly be tolerated by the body without ill-effects. Such standards also apply in the case of radiation.

In the therapeutic application of radiation, the idea of the tolerance dose is a current notion. It signifies the amount of radiation which the tissue concerned is still able to tolerate. Experience has shown, however, that such a dose cannot be regarded as entirely harmless; for even though, after its administration, the tissue undoubtedly undergoes none of the morphological alterations which are known as Roentgen injuries, yet it is left with a reduced power of resistance to otherwise inoperative influences. Further investigations have shown that this *locus minoris resistentiæ* is engendered even by doses equivalent only to 50 per cent of the tolerance dose. This holds good for all kinds of tissue, even though the radio-sensitivity, and thereby the tolerance dose, differs for each.

The above observations show that the tolerance dose is never a harmless one and that tolerance doses can in no case be readministered indefinitely to any particular piece of tissue after the visible effects have disappeared on each occasion.

The only dose, therefore, that could be harmless, would be one which would produce no effect whatever, on the particular piece of tissue concerned and could hence be administered *ad libitum.*

The conditions to be fulfilled by such a " tolerance dose " are thus very stringent, and would seem to warrant the question whether such a dose can exist at all. In the first place, however, the mode of action of the rays must be briefly discussed.

If Roentgen or radium rays are directed on to living cells, part of the radiant energy is absorbed. The only elementary process which is known with certainty to occur when X-rays impinge upon a material object is the ejection of electrons. A state of greater energy is thus induced in the atom. When it reverts to a condition of lower energy, a form of radiation known as fluorescent radiation occurs. The collision of electrons may also release the acquired energy in the form of kinetic energy (thermal motion) or chemical activity.

If a large part of the radiation is absorbed, there is an accession of energy to numerous cell molecules, the electronic paths are deflected, chemical activity takes place, heat and radiation are engendered. This energy exceeds the measure which is compatible with the life activity of the cell; its functions are disturbed or it dies.

Such an accession of energy occurs, however, even on absorption of a very slight amount of radiation. Only a few molecules are stimulated, and the life activity of the cell is intensified.

Similar facts have long been known in respect of light and heat. There is no reason for not assuming that they apply also to energy taken up in the form of absorbed X-rays. Stimulating effects, produced by the administration of X-rays in small amounts, have already been observed by numerous research workers.

We thus reach the conclusion that a really harmless dose of radiation can only be said to be given if it is incapable either of destroying or damaging the cells, or of exercising any stimulating action.

The exact determination of such a dose would seem to be impossible. We must accordingly be content to speak of a harmless dose, whenever no alteration in the condition and activity of the body can be detected by available methods of clinical examination and observation.

This, moreover, has been the principle adopted in the investigations undertaken with the object of determining the magnitude of a harmless X-ray dose.

I think it necessary, however, to refer to a further point of clinical experience.

Just as the organism is known to possess powers of habituation to certain poisons, so the body cells are similarly able to neutralise small amounts of X-rays. We observed this capacity of the cells for habituation when administering therapeutic amounts of radiation by fractional doses. If 100 per cent of the skin unit dose, instead of being given in half an hour, is distributed over 5 days, 20 per cent of the skin unit dose being given on each occasion, the biological effect is about 35 per cent less powerful than when the whole dose is administered at a single sitting. In distant field radiation, also we know that the conversion must not be made by the law of inverse squares, but that the computed dose must be increased by the amount of radiation which is termed the additional biological dose (" Biologische Zusatzdosis "). All this indicates that the cell is able to deal rapidly with the energy of small amounts of X-rays, and that a particular effect cannot be secured by adding together the several doses separately given.

The administration of a specific amount of radiation at one sitting thus produces a different effect from the gradual absorption of the same amount as occurs, let us say, in the case of attendants. A comparison of the biological action is doubtless not legitimate, for, when the absorption of rays is distributed over a lengthy period, habituation becomes so important a factor that much of the radiation taken up in the body is wholly without biological effect.

1. *The Magnitude of the Tolerance Dose.*

We will now consider the tolerance dose with reference to the dose injurious to the operator. We are tied down to the technical terms of measurement which apply in radiation of patients. The foregoing observations will, however, have made it clear that these numerical data can only be of conditional validity.

Reliable measurements have only been obtainable from X-ray establishments quite recently, when protection from rays had already received considerable attention. It would doubtless be interesting to go back and compute the amount of radiation absorbed in former years by the persons who sustained injuries. But such reconstruction is now impossible, for we must remember that in these cases the injuries — let us say severe lesions of the hands — were not caused by the radiation alone, but by other factors such as developing chemicals or disinfectants. The ill-effects of tainted air in small unhygienic X-ray theatres must also be taken into account. To this must be added the fact that the inadequate screening of Roentgen tubes gave rise to fields of radiation that were dangerous in certain parts of the various rooms and less so in others.

Hence it is, that correct measurement only became possible for the first time in establishments with modern equipment and totally encased Roentgen tubes.

Complete protection from very short wave-length radiation (hard X-rays, gamma rays) is technically impossible owing to their great power of penetration; all that can be done is, by increasing the distance from the source and by the interposition of protective material, to attenuate the radiation to a point at which the residual intensity causes no appreciable injury to the human organism even on constant exposure. It is, in the nature of things, extremely difficult to assign any specific numerical value to such a tolerance dose, and there is consequently very little previous work in this field to fall back on for guidance.

The first attempt to define the tolerance dose in terms of a numerical value was made by Mutscheller. [1] He based his computations on several typically good installations in X-ray establishments, and found that, in the course of one month, the staff absorbed 1/100th of an erythema dose (skin unit dose). On the assumption of 200 hours' work per month, it was concluded that radiation should be regarded as harmless if weaker than would be required to produce " erythema in 20,000 hours " (with 8 hours' exposure per day it would take about 8 years to reach the figure of 20,000 hours).

In this form, the definition of a tolerance dose cannot be very readily used. The figures are obtained from a comparison of the X-ray dose measured at a particular spot in the radiation theatre, with the dose of radiation required to produce skin erythema or pigmentation under ordinary conditions of radiation, i.e., exposure for a short time. Account has not been taken of the fact that, when the period of radiation is so enormously prolonged, the time factor (the biological additional dose) must assume considerably greater proportions. If we proceed to extrapolate from the values determined for prolonged and discontinuous radiation, we shall arrive at a time-factor value of about 10; yet, even if the specified intensity of radiation is increased tenfold, no erythema or pigmentation will ever be produced. Even when, under the conditions of less adequate protection than usually prevailed in the past, the organism received a dose some hundred times as great, the skin was never affected, but the injury took the form of alterations in the blood composition. Only after a number of years, when still higher doses had been repeatedly absorbed, did skin affections set in, developing, in certain cases, into X-ray cancer. (An attempt recently made by us to produce such skin injuries

[1] *American Journal of Roentgenol.*, 13, 53, 1925.

deliberately in animals gave a negative result; the radiation of mice with 6-60 *r* for an hour each day, on the same skin field, produced no discernible signs of a skin reaction even after a considerable time.)

If MUTSCHELLER's figures are to be used, it will be best to express the skin unit dose, i.e., the amount of radiation which, with the short-time method of administration, produces a definite, harmless skin reaction, in *r* units (international Roentgen units). A circular enquiry instituted at one time by Küstner [1] yielded an average value for Roentgen radiation, as currently used in deep therapy, of : 1 skin unit dose = 550 R (without the additional dose of scattered radiation) or, since 1 R = 1.066 *r*, 1 skin unit dose = roughly 600 *r*. We shall be conforming to MUTSCHELLER's method, if we disregard the time factor, in which case the tolerance dose works out at 1/100th skin unit dose, or 6 *r* per month, or, assuming 200 working hours per month, about 1×10^{-5} *r*/sec.

GLOCKER and REUSS [2] and BEHNKEN [3] assume the same value, BOWERS and VAN DER TUUK [4] 0.7×10^{-5} *r*/sec. BARCLAY and COX [5] reported a case in which 0.007 skin unit dose per diem was tolerated for 6 years without ill-effects ; on the basis of an eight-hour day, this would represent a dose of 15×10^{-5} *r*/sec. CHANTRAINE and PROFITLICH [6] compute the dose at 0.05 to 0.1 *r* per hour, or 1.4×10^{-5} *r*/sec. SOLOMON [7] assumes that 4,000 R per annum is harmless ; on the basis of 300 eight-hour days, this would equal approximately 7×10^{-5} *r*/sec. SCHECHTMANN [8], on the other hand, is of opinion that the tolerance dose should only amount to 1 *r* per month, since the ionisation of the air in the radiation theatre is not without importance to the staff. FRICKE and BEASLEY [9] and JACOBSON [10] took direct measurements at various clinics in Cleveland and New York, and found that, there, 24 R at most were absorbed per year (2.4 per cent of a kilo-roentgen per year) which would amount to 0.3×10^{-5} *r*/sec. No blood changes whatever were observed, not even in a roentgenologist who worked without a lead rubber apron and absorbed about 5 R per hour (0.5 per cent of a kilo-roentgen hour) or about 150×10^{-5} *r*/sec. (!). My own experience would lead me to regard 10×10^{-5} *r*/sec. as safe. Since, however, the general standards of safety must on no account be set too low, the *admissible dose output* [11] will be taken, in the following pages, at 1×10^{-5} *r*/sec., assuming an eight-hour day and 300 working days per year. In the case of persons who remain constantly in proximity to sources of radiation giving off rays without intermission (radio active preparations) the tolerance dose should be proportionately reduced, so that a dose output of $\frac{1}{3} \times 10^{-5}$ *r*/sec. could be held to be harmless.

These requirements appear, at first sight, exaggerated; for what I have defined as permissible absorption of radiation represents about 12 per cent of the skin unit dose. In connection with the question of injuries caused by pelvic photographs, we ascertained on one occasion that the absorption of 5 per cent of the skin unit dose at a single

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[1] *Strahlenth.*, 26, 120, 1927.
[2] *Fortschritte Röntgenstr.*, 40, 501, 1929.
[3] *Fortschritte Röntgenstr.*, 41, 245, 1930.
[4] *Fortschritte Röntgenstr.*, 41, 767, 1930.
[5] *American Journal of Roentgenol.*, 19, 551, 1928.
[6] *Fortschritte Röntgenstr.*, 38, 121, 1928.
[7] *Précis de Radiothérapie profonde*, Paris, 1926.
[8] *Fortschritte Röntgenstr.*, 42, 645, 1930.
[9] *American Journal of Roentgenol.*, 18, 146, 1927.
[10] *American Journal of Roentgenol.*, 18, 149, 1927.
[11] The term " dose output " used here and elsewhere purports merely to be, as nearly as possible, a literal rendering of the German " Dosisleistung " and must be read as having the meaning of " Dosisleistung ".

sitting must be regarded as harmless. According to the standard just set, 12 per cent of the skin unit dose is administered to the human organism in the course of a year. It is therefore an amount of radiation which can be pronounced harmless with absolute certainty, and, if my own experience leads me to regard ten times this amount, i.e., 120 per cent of the skin unit dose, as harmless when distributed over a whole year, the most stringent requirements in respect of protection have undoubtedly been satisfied. The conditions laid down may, in themselves, be greatly exaggerated, but they can assuredly be fulfilled under present-day conditions. Careful measurements in my various radiation theatres have shown that a dose output of 1×10^{-5} *r*/sec. is nowhere reached. There is hence no reason to reject the standard defined out of hand on the plea that it would be technically impossible to attain.

2. *Means of reducing the Dose Output.*

Every radiation emitted from a source of small and limited spatial extension obeys the so-called law of inverse squares, that is to say, that the intensity of radiation dose output, varies in inverse proportion to the square of the distance from the source. The first requirement for effective protection from rays is therefore that the distance from the source of radiation should be made as great as possible.

Furthermore, the dose output is reduced by the passage of the radiation through a material substance (protective material, masonry), this reduction taking place according to the formula:

$$D = D_0 \,.\, e^{-\mu \cdot d},$$

D_0 being the dose output before passage through the attenuating material, D the dose output as attenuated by the material, e the value 2.718, μ the coefficient of attenuation and d the thickness of the material (in centimetres). The dose output of the emergent rays is thus the smaller the smaller the original dose output D_0 and the greater the coefficient of attenuation μ and the thickness d of the protective material.

The dose output at a spot situated at the distance a from the source of radiation, in the case of radiation which has first passed through an attenuating substance, is obtained by the equation :

$$D = D_o \cdot \frac{e^{-\mu d}}{a^2}.$$

D_0 being the dose output in a distance of 1 cm.

According to what has been said above, if adequate protection from radiation is to be afforded, the dose output D should not exceed 1×10^{-5} *r*/sec. Hence :

$$10^{-5} = D_o \cdot \frac{e^{-\mu d}}{a^2}.$$

From this we can obtain the thickness d of protective material required given a particular distance a from the source of radiation:

$$d = \frac{2.3}{\mu} \,.\, (\log D_0 - 2.\ \log a + 5),$$

and the distance a at which, given a particular thickness d of protective material, the radiation is harmless:

$$a = 316 \,.\, \sqrt{D_0 \,.\, e^{-\mu \cdot d}}$$

This distance a might be termed the "range" of the radiation.

From the above equations, the values of d and a can be computed for particular conditions of ray emission. There are, however, one or two difficulties to be cleared up first. These relate to the determination of the initial dose output D_0 and of the coefficient of attenuation μ.

In the first place, the Roentgen rays will be considered.

3. *The Dose Output of a Roentgen Tube.*

The dose output of a Roentgen tube depends, first, upon the voltage in the tube, secondly, upon the current in the tube, thirdly, on the material of the anti-cathode. The form of the tension curve, whether continuous or pulsating tension, is also a factor, but these differences may be disregarded here. So far as the applied cone of radiation is concerned, filtering is obviously also of considerable importance.

We will dispose first of the material of the anti-cathode. The intensity of the white radiation, which is the main consideration, increases proportionately to the atomic number of anti-cathode material. The substance principally used nowadays is wolfram, with an atomic number of 74. The only substance of higher atomic number which might be considered would, for the moment, be platinum, with an atomic number of 78. The difference is so slight that it will be sufficient to base our considerations on wolfram; if substances of lower atomic number are used, the dose output grows steadily smaller.

Of the remaining two factors, voltage and current, voltage is by far the more important, since the dose output of the beavily filtered radiation, with which we are always concerned when dealing with protective materials, increases roughly in proportion to the cube of the voltage in the tube [1] whereas it remains in direct proportion to the current. For this reason, the regulations hitherto published on the subject merely refer the required thickness of protective material to the tube voltage and entirely ignore the current.

In my opinion, such provisions are inadequate; especially where the technical examination of materials is concerned. But in Roentgen therapy also, with distant field radiation, when high tensions are used, currents of 50 ma and more are reached. In medical X-ray diagnosis currents rising to 1,000 and 2,000 ma are used, though admittedly only for short periods. The current in the tube must therefore also be taken into account, for the dose output at 30 ma, for instance, is ten times as great as at 3 ma, and the dose output beyond the protective material is proportionately increased.

For these reasons, the thickness of the protective material must be determined by reference, not merely to the tube voltage, but to the dose output, and we must first enquire how the dose output can be ascertained from the voltage and current in the tube. For this purpose, it will be best to take the energy of the Roentgen rays as a starting-point.

Since the classical gas X-ray tubes are no longer in use save in a few exceptional cases, consideration may be limited to the modern incandescent cathode tubes. The efficiency of the latter in respect of X-ray production is sufficiently well known. The following observations are based upon the energy measurements of Rump [2]. The total quantity of radiant energy emitted from the Roentgen tube is equivalent to:

$$E = 1.5.i\ V^2.Z.10^{-9}\ \text{Watts.}$$

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[1] Rump : *Z. Physik.*, 43, 254, 1927 ; Behnken, *Fortschritte Röntgenstr.*, 41, 245, 1930.

[2] *Z. Physik.*, 43, 254 and 44, 396, 1927 : cf. also Kirchner : *Allgem. Physik d. Röntgenst.* Volume 24, 1, of the *Handb. der experiment. Physik*, page 113, Akad. Verlagsgesellschaft, Leipzig, 1930.

i being the current in the tube in ampères, V the tension in the tube in volts, Z the atomic number of the anti-cathode material. If $Z = 74$ (wolfram anti-cathode), the equation reads:

$$E = 111.i.V^2.10^{-9} \text{ Watts.}$$

This total energy spreads out in all directions from the focal point, so that, at a distance of a cm. from the focus, a quantity of energy equivalent to:

$$E' = \frac{9 \cdot i \cdot V^2}{a^2} \cdot 10^{-9} \text{ Watts}$$

impinges on each square centimetre of surface.

This formula applies to the total radiation as emitted by the anti-cathode of the Roentgen tube. Such radiation is known to be very unhomogeneous, and covers a very wide field of the spectrum, beginning at the boundary wave-length determined by the voltage and extending to very long-wave rays. The latter are already largely absorbed in the anti-cathode and in the glass wall or the lumen of the Roentgen tube, so that the radiation becomes more and more homogeneous the more absorbent material it passes through. Thus, for instance, about 80 per cent of the total energy is lost in an ordinary filter of the kind used in deep therapy. The powerful filtering process that takes place in the protective materials arrests the whole of the soft components and the radiation is thus rendered largely homogeneous. In order to allow for this, a homogeneisation factor must be introduced, which — to be sure — is not entirely independent of the tube voltage. It will be sufficient for present purposes to take an average value, empirically determined, and to express the hardest components of the radiation, i.e., those that matter so far as the penetration of the protective material is concerned, by the equation :

$$E'' = \frac{i \cdot V^2}{a^2} \cdot 10^{-10} \text{ Watts/sq. cm.},$$

or, in terms of ergs:

$$E'' = \frac{i \cdot V^2}{a^2} \cdot 10^{-3} \text{ ergs/sq. cm.}$$

This is therefore the effective amount of radiant energy, which was represented above by D_0 and which, on passing through protective material, is attenuated in accordance with the formula previously given

$$(D = D_0 \cdot e^{-\mu \cdot d}).$$ [1]

For purposes of conversion into the current r dose unit (international Roentgen unit), which is based upon ionisation of the air, the amount of energy must be known which is required to produce a pair of ions in the air. As a mean value resulting from the investigations carried out in recent years by Kulenkampff, Rump, Eisl and others, this amount of energy may be taken at 33 volts, irrespective of the wave-length of the radiation. From this it follows that $1\ r = 0.11$ ergs of energy absorbed in 1 ccm. of air at 0°C. and at a pressure of 760 mm. of mercury ; and we then get

$$D_0 = 1.25 \cdot \frac{i \cdot V^2}{a^2} (\tau/\rho) \cdot 10^{-5}\ r\text{/sec.},$$

[1] It is clear that so large a correction cannot be attended with any very great accuracy, but the object here is not to make an exact determination of the energy, but rather to find a formula which tallies with previous evidence and enables the dose output to be split up into its factors, so that the thickness of protective material required can be determined, not only for various voltages, but also for any modification of the tube current and of the focal distance.

τ/ρ being the total mass absorption coefficient of the air [1] which depends in a large measure on the wave-length and can be ascertained from curves. [2]

With a residual radiation $D = 1 \times 10^{-5}$ r/sec. on the far side of protective material having a thickness of d cm., this works out at

$$e^{\mu \cdot d} = 1.25 \cdot \frac{i \cdot V^2}{a^2} \cdot (\tau/\rho).$$

4. *The Coefficient of Absorption of Lead.*

The second difficulty resides in the determination of the coefficient of absorption μ, which is largely dependent on wave length. In practice, the only protective material to be considered is lead, and only the coefficient of absorption of lead need be determined, since an equivalent thickness of lead can always be calculated for other materials.

The difficulties attaching to the determination of μ reside, first, in the non-homogeneous composition of the radiation, and, secondly, in the fact that the range of wave lengths most frequently used for technical purposes encompasses a zone of selective absorption.

Behnken [3] therefore proposed to use, not the coefficient of absorption, but the half-value layer of the radiation, to determine the requisite thickness of lead. Behnken [4] gives a series of curves showing the fraction to which radiation of a specific half-value layer is reduced by passing through lead of a particular thickness. It should be observed, however, that the half-value layer can only afford an unequivocal measure of the quality of the radiation, if the radiation is homogeneous or at any rate " practically homogeneous ". In practice, however, radiation is very frequently used that is by no means "practically homogeneous". To this it should be added that the point to be considered in this case is solely that of protection from the radiation present in the room, outside of the applied cone, and that this radiation has no direct relationship to the applied cone. The effect of Behnken's proposal would be that a Roentgen tube operating under specific unchanging conditions would require increasing thicknesses of lead protection as the filtering of the applied beam became greater. For instance, radiation produced with an input of 200 kv and filtered with 0.5 mm. Cu., as illustrated in Plate 1 (*op. cit.*, page 246) has a half-value layer of 1.1 mm. Cu.; this radiation is reduced to $\frac{1}{1000}$ of its intensity by 2.3 mm. Pb. If the same radiation is filtered in the applied cones with 1 mm. Cu., the resulting half-value layer is 1.5 mm. Cu. ; in order to attenuate this radiation to $\frac{1}{1000}$ of its intensity, 2.9 mm. Pb. would be needed. If the same radiation is filtered in the applied cone, with 2 mm. Cu., the half-value layer works out at 1.9 mm. Cu., for radiation of this quality, the requisite thickness of lead can no longer be read from Chart 7 (*op. cit.*, page 249), since the curves rise very steeply from 1.7 mm. half-value layer onwards.

It is not practicable in my opinion to make the requisite protective thickness of lead dependent upon chance factors, such as the filtering of the applied cone, which varies considerably in practice. If, however, it is tacitly assumed that the radiation must, so far as possible, be homogeneous, the method amounts to nothing more than a determination of the coefficient of absorption, since for homogeneous radiation we have the equation: μ. half-value layer $= 0.693$.

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[1] Wintz and Rump in the *Handb. d. Gyn.*, published by Stoeckel, Volume IV, 1, page 401, published by J. Springer, Berlin, 1930.
[2] *Ibid.*, page 325, plate 108.
[3] *Fortschritte Röntgenstr.*, 41, 245, 1930.
[4] *Ibid.*, page 249, plate 7.

Inevitably, therefore, we must fall back on the primary radiation emitted by the Roentgen tube and endeavour to get round the difficulties attaching to the determination of the coefficient of absorption.

These difficulties lie, as already mentioned, in the non-homogeneous composition of the radiation and in the selective absorption of lead.

So far as the lack of homogeneity of the radiation is concerned, this consists in the fact that the spectrum of white radiation contains a continuous series of wave lengths, beginning at the boundary wave length, rising to a maximum, and extending into the long wave lengths. By filtering of the radiation, the spectrum is narrowed down in such a way that, with increasing thicknesses of filtering material, the long-wave end and the maximum shift towards the short-wave end. When the filtering in the protective material is very strong, as it must be to reduce the dose output of the tube to the tolerance dose, the medium wave length of the residual radiation can be roughly identified with the boundary wave length, which is directly related to the peak voltage of the tube by the Planck-Einstein law ($\lambda_o V_{max} = 12.35$); the experimental values determined for homogeneous radiations can thus be used.

In this connection, very detailed measurements of the coefficient of absorption in its relation to wave lengths have been made by Allen [1]. The values for lead are charted in Graph I (see Annex) in such a way that the voltages yielded by the Planck-Einstein law are given instead of the wave lengths. The squaring adopted has been that of a logarithmic scale in both co-ordinates; the curves are thereby flattened out into straight lines, and we thus obtain the line A-B-C-D, which makes a sudden jump at 89 kv., corresponding to the absorption edge of lead. This can only occur, of course, with purely homogeneous rays, whereas, if they are not homogeneous, the jump flattens out into a curve affording a smooth transition from the straight line A-B to the straight line C-D. This can be seen, for instance, in the measurements taken by Kaye [2] and Berthold [3] and by Glocker and Reuss [4]. These measurements also show, however, that the coefficient of absorption diminishes with increasing thicknesses of lead, and only becomes constant with a fairly powerful lead filter. This is due to the fact that the homogeneisation of the radiation progressively increases with increasing thicknesses of the attenuating substance. This behaviour is particularly well illustrated by the curves published by Herrmann and Jaeger [5] and by a recent paper of Glocker and Reuss [6], in which it is shown that the coefficient of attenuation of lead for 200 kv. only reaches its constant minimum value with 4 mm. of lead. The measurements of Herrmann and Jaeger (*op. cit.*) cover voltages up to 400 kv. and thus provide a highly valuable transition to the radium gamma rays. Using these experimental results, and plotting the attenuation coefficient values for tensions of 70 kv. and 100 kv. by extrapolation from the measurements of Kaye (*op. cit.*), we obtain the curve appearing as a produced line in Graph I as the trend of the coefficients of absorption. The plotting of the experimentally determined points shows, more especially in the zone of high tensions, that the radiation behaves as practically homogeneous when subjected to the very heavy filtering which is necessary for protective purposes.

As will be seen from the table on page 17, the thicknesses of lead yielded by this curve agree satisfactorily with the values hitherto regarded as correct ; it should not be

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[1] *Physic. Rev.*, 24, 1, 1924 ; 27, 266, 1926 ; 28, 907, 1926.
[2] *Brit. J. Radiol.*, 1, 295, 1926.
[3] *Strahlenther.*, 16, 147, 1923.
[4] *Fortschritte Röntgenstr.*, 40, 501, 1929.
[5] *Ibid.*, 42, 115, 1930.
[6] *Ibid.*, 42, 651, 1930.

overlooked, however, that, at low voltages (70 and 100 kv.) the thicknesses of 1 and 1.5 mm. of lead do not produce complete homogeneisation, so that higher coefficients of reduction should really be used in calculation; the homogeneisation factor (see above) would, however, have to be reduced. The two factors offset each other and result in a certain balance being established ; direct measurements by Glocker and Reuss [1] have shown, however, that, with a current of 5 ma on the tube, a focal distance of 30 cm. and 80 kv. pulsating tension, a residual radiation emerges from the far side of 1 mm. Pb. which is forty times the permissible value; even with 2 mm. Pb. the emergent radiation was 4-5 times the tolerated dose with a voltage of 80 kv. 17 times with 100 kv. and 33 times with 115 kv. Glocker and Reuss [1] comment on this result in the following terms:

" In laying down minimum thicknesses in regulations for protection from radiation there are, it is true, certain practical considerations to be borne in mind as well; the period during which the apparatus is operated in diagnostic establishments is shorter than in therapeutic establishments, so that a somewhat larger dose may be regarded as harmless in the former case. "

The said authors [2] add that, in the German regulations concerning protection from radiation, the permissible dose has been fixed approximately ten times higher for diagnostic work than for deep therapy.

It should further be observed that general regulations governing protection from radiation are not intended solely for medical establishments and that, in Roentgen tube factories, scientific laboratories, etc., work is frequently carried on for hours at a stretch with low voltages but powerful currents. In view of this, further detailed investigations would be necessary.

5. *The Requisite Thickness of Lead considered in Relation to Voltage, Current in the Tube and Distance.*

With the aid of the curve in Graph I all questions as to the required thickness of protective material with various voltages, currents and distances can be answered in such a way that the dose output does not exceed 1×10^{-5} *r*/sec.

On this basis, Graph II shows a set of curves from which it is possible to determine what thickness of lead is necessary, with a particular voltage, if, given a focal distance of 50 cm. the tolerance dose is not to be exceeded with 1 ma, 10 ma and 100 ma of current. Thus, for instance, the requisite thickness of lead is indicated as 3.2 mm. for 150 kv. in the tube and 10 ma.

Graph III gives a further set of curves which indicate what thickness of lead will be necessary, with a current of 10 ma, in order that the tolerance dose may not be exceeded with focal distances ranging from 10 cm. to 20 m. It will be found, for instance, that with 200 kv. of current and a focal distance of 2 m. the requisite thickness of lead is 3.6 mm. The curves further show, for example, that, when the conditions remain unchanged (200 kv. and 10 ma) and 2 mm. of lead is used, the range of the injurious Roentgen radiation is about 8 m.

If it is desired to compare the results yielded by these curves with the specifications in the international or German regulations, this comparison cannot be directly effected, since, as already mentioned, the current is not stated and the regulations concerning focal distance are greatly lacking in precision. The international regulations, for instance,

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[1] *Fortschritte Röntgenstr.*, 40, 504, 1929.
[2] *Fortschritte Röntgenstr.*, 42, 656, 1930.

state under Chapter III, 11: "An operator should place himself as remote as practicable from the X-ray tube". The German regulations provide that persons remaining in the treatment rooms must keep at a minimum distance of 1.5 m. for maximum voltages up to 125 kv. and at a minimum distance of 2 m. for maximum voltages above 125 kv.

Assuming a current of 5 ma and a focal distance of 1 m. we obtain the following table which enables comparisons to be made:

Tube voltage	Regulations		Values yielded by Graphs II and III
	International	German	
Up to 75 kv	1.0 mm. Pb	1.0 mm. Pb	1.1 mm. Pb
,, 100 ,,	1.5 ,, ,,	—	1.5 ,, ,,
,, 125 ,,	2.0 ,, ,,	2.0 ,, ,,	2.0 ,, ,,
,, 150 ,,	2.5 ,, ,,	—	2.3 ,, ,,
,, 175 ,,	3.0 ,, ,,	—	3.0 ,, ,,
,, 190 ,,	—	3.0 ,, ,,	3.5 ,, ,,
,, 200 ,,	4.0 ,, ,,	—	4.0 ,, ,,
,, 220 ,,	—	5.0 ,, ,,	4.9 ,, ,,
,, 225 ,,	5.0 ,, ,,	—	5.2 ,, ,,
,, 300 ,,	—	—	10.3 ,, ,,
,, 400 ,,	—	—	20.0 ,, ,,

This table will show that the thicknesses of lead computed from the curves agree satisfactorily with current standards; what was said above must however be borne in mind where low voltages are concerned.

If the current in the tube is increased tenfold, the residual radiation on the far side of the protective material is of course ten times as great as before. If the thickness of the protective layer was calculated for 10 ma, the dose output of the residual radiation delivered at the point considered by 100 ma of current is thus no longer 10^{-5} r/sec. but 10^{-4} r/sec. The additional thickness necessary to make up for the difference can easily be computed from the attenuation formula ($D = D_0 . e^{-\mu . d}$); it works out at

$$d - d_1 = \frac{2.3}{\mu}$$

For radiation produced with a voltage of 100 kv., Graph I will show, for instance, that $\mu = 33.5$, which means that $d - d_1 = 0.7$ mm. In other words, if the dose output is multiplied by 10, the thickness of lead, with a voltage of 100 kv. must be increased by 0.7 mm.; similarly if the dose output is reduced to one-tenth, the thickness of lead can be diminished by 0.7 mm.

In general terms, the relation of the dose output to varying thicknesses d of lead can accordingly be expressed as follows:

$$\log (D/D_1) = 0.434 . \mu . \ (d - d_1).$$

If, for instance, with a voltage of 200 kv. ($\mu = 16.2$) the lead thickness of the protective material is changed by 1 mm. ($d - d_1 = 0.1$ cm.), then $D/D_1 = 5$, which means to say that, if the thickness of lead is increased from 4 to 5 mm., the dose output is reduced to one-fifth; if, on the other hand, the thickness of lead is reduced from 4 to 3 mm. the dose output is multiplied by 5. The effect of a 1 mm. change in the thickness of lead increases with diminishing voltages.

The scant measure of subdivision in the graded series of lead thicknesses laid down in the German regulations is doubtless attributable to a statement by Glocker [1] who held a subdivision for 125, 150 and 175 kv. to be unnecessary owing to the small reduction of the coefficient of absorption between 100 and 200 kv. Subsequently, however, van der Tuuk and Boldingh [2] challenged this statement, and Glocker [3], in a recent publication, has somewhat changed his view.

In my opinion, as will be gathered from what precedes, it is not sufficient merely to graduate the thicknesses in accordance with the voltage, and the series should at any rate be extended upwards, since it has latterly been possible to operate Roentgen tubes with 400 kv. [4], 600 kv. and 750 kv. [5] When 400 kv. is used, it will be seen, for instance, from Graph II that, with a current of 1 ma and 50 cm. focal distance, as much as 20 mm. of lead is necessary to reduce the dose output to the permissible value.

Since there may, in some cases, be considerable differences in the currents used in the tube, it is, in my opinion, necessary that the scope of the provisions should be suitably widened, or at any rate that the possibility of determining the necessary thicknesses of lead in each separate case should be left open.

6. *Protection of Adjacent Rooms.*

As regards the protection of adjacent rooms, this, of course, is only necessary if the tube holder does not already provide adequate protection; it is further assumed that the applied cone is also suitably screened. If the tube is not adequately protected, the determining factor will be the protective value of the partition walls, allowing for focal distance.

Graph III gives particulars of the reduction of the lead thickness (or lead value) required in the partition walls as the distance from the Roentgen tube increases. It will be seen that, for instance, with 200 kv. tube voltage, 10 ma current and a focal distance of 8 m., the thickness of the partition wall must be equivalent to 2 mm. of metallic lead.

As regards the protective value of current building materials and of special substances manufactured for protective purposes such as lead glass, lead rubber, baryta walls, etc., various studies have already been made, e.g., by Kaye and Owen, by Berthold, by Berthold and Glocker, and, more recently by Sievert and Thoraeus; the last-named have collated the results obtained by the other authors mentioned [6].

In the above example, 2 mm. of metallic lead would hence correspond to about 20 cm. of brick wall, that is to say, a wall with a thickness of one brick, assuming the size of a brick to be $6 \times 12 \times 25$ cm. Under the conditions specified, such a thickness of wall thus affords adequate protection, even if the Roentgen tube is wholly unprotected or if direct radiation from the target impinges with its full intensity on the particular spot considered. Timbering of the same thickness naturally affords less protection, and the protective value of the partition wall must be ascertained in each separate case. Even where, under the conditions specified above, the focal distance is 20 m., it will be seen from the curves that lead protection of 0.8 mm. Pb., or a wall about half a brick thick is necessary.

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[1] *Fortschritte Röntgenstr.*, 40, 501, 1929.
[2] *Ibid.*, 41, 965, 1930.
[3] *Ibid.*, 41, 969, 1930.
[4] Herrmann and Jaeger, *Fortschritte Röntgenstr.*, 41, 426, 1930.
[5] Lauritsen and Bennett, *Physic. Rev.*, 32, 850, 1928.
Lauritzen and Lassen : *Physic. Rev.*, 36, 988, 1930.
[6] *Acta Rad.*, XI, 342, 1930.

Since the intensity of the radiation diminishes proportionately to the square of the distance, increasing the distance is a very effective means of protection from radiation. From the equation given above ($a = 316 . \sqrt{D_o . e^{-\mu . d}}$) we obtain the ratio of two ranges — namely, $a/a' = \sqrt{D_o/D'_o}$. If, for instance, the range of the injurious radiation with a tube voltage of 180 kv and a current of 5 ma is to be determined for a protective wall of 2 mm. lead equivalent, Graph III will show the range to be 5 m. with 180 kv and 10 ma. For half that intensity (5 ma), the range thus equals $5\sqrt{2} = 3.5$ m.

Again, it is easy to ascertain what reinforcement of the lead protection is necessary if the dose output is raised. The above formula yields :

$$d - d' = \frac{4 \cdot 6}{\mu} . \log (a/a')$$

$$= \frac{2 \cdot 3}{\mu} . \log (D_o/D'_o)$$

If, for instance, the voltage being 180 kv, the current is increased from 5 ma to 20 ma, then, in order that the protection from radiation may be the same — i.e., in order that the injurious radiation may have the same range — the thickness of the wall must be increased by (2.3×20) . log 4 = 0.07 cm. = 0.7 mm. lead equivalent. If this reinforcement is not effected, the range increases from 3.5 m. to 3.5 m. $\sqrt{4} = 7$ m.

In the manner indicated, the requisite protection can be determined for all the various conditions of operation that may occur.

The data given are also sufficient for extreme cases. Herrmann and Jaeger [1], for instance, have taken direct measurements with a view to ascertaining what thicknesses of lead are necessary, given X-rays generated with 400 kv, to secure the same protection as is afforded, with 200 kv by 4 mm. of lead. No attention appears to have been paid in either case to the current in the tube ; the measurements indicated, however, the need for 14.5 mm. of lead with 400 kv and 0.5 ma. Graph II, on the other hand, gives, for 400 kv, 1 ma and 50 cm. focal distance, a lead thickness of 19.5 mm.; converting this into terms of 0.5 ma, we get 17.7 mm. Pb. and, reckoning 1 m. focal distance, we obtain the value of 14.1 mm. Pb. This satisfactory concordance with the value ascertained by direct measurement can be taken as confirmation of the fact that the data on which the curves have been constructed are adequate for practical purposes.

7. *Protective Measures from the Gamma Rays of Radio-active Substances.*

We must now enquire whether and, if so, how far, the curves given can be used for the gamma radiation of radio-active substances.

In order to establish a connection between gamma radiation and the radiation of an X-ray tube, we must return to the question of energy and determine the voltage and current at which a Roentgen tube would have to be operated in order to emit the same radiant energy as, say, 1 gramme of radium.

Consideration of the gamma rays will be based upon the most commonly used substance, RaC. This consists of several homogeneous groups of various wave lengths, of which the 0.02 Å. U. wave length is the most intense. Gamma radiation is thus also not homogeneous, but it is much more so than Roentgen radiation, even if the latter is very heavily filtered. By way of absorption measurements, we obtain an average wave

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[1] *Fortschritte Röntgenstr.*, 41, 426, 1930, and 42, 115, 1930.

length which corresponds, according to Compton [1], to 0.016 Å. U. According to the Planck-Einstein law this would represent a voltage of 770 kv. If, however, a Roentgen tube is operated at this voltage, only the boundary wave length is at 0.016 Å. U., and the corresponding radiation has the intensity O. Consequently, a higher voltage must be used, so that the wave length 0.016 Å. U. is located at the point of maximum intensity. According to Dauvillier, [2] this is effected if the voltage is raised in the proportion of 1,3. A Roentgen tube would thus have to be operated with 1.3 . 770 = 1,000 kv, to emit radiation of the average gamma-ray wave length.

As regards the coefficient of absorption of gamma rays for lead, the values ascertained have varied owing to their lack of homogeneity. According to experiments by Ishino [3] it is 0.826, whereas, according to Kohlrausch [4] the coefficient of absorption decreases with increasing thicknesses of lead, and attains the constant value of 0.533 from 3.5 cm. of lead upwards. Graph I gives 0.55 for a tube voltage of 1,000 kv, thus agreeing satisfactorily with the above-mentioned result.

According to Ellis and Wooster [5], the energy of the gamma rays of 1 gr. of radium is equivalent to 8.6 gramme-calories per hour ; this represents 10^5 ergs per second. This amount of energy is emitted into the room in the form of spherical waves ; the amount of energy incident upon 1 sq. cm. at a distance of a cm. from the source of radiation being $\frac{10^5}{4} .. \pi . a^2$ erg./sec. Expressed in r units this represents, as already demonstrated in detail for X-rays, $\frac{10^5 . 0{\cdot}02}{4 a^2 . 85} = \frac{1{\cdot}88}{a^2}$ r /sec., taking the total mass absorption coefficient of the air to be 0.02. In this conversion, it is assumed that the value of 33 volts per pair of ions, which was determined in connection with X-rays, also applies to gamma rays. Strictly speaking, in this case as in that of X-rays, a homogeneisation factor should be introduced. For gamma rays, it is, however, so small that it may be neglected.

A comparison with the energy output of a Roentgen tube shows that such a tube, operating with 1,000 kv voltage and powerful homogeneisation, would require a load of about 0.02 ma to generate the same amount of radiation as the gamma radiation of 1 gramme of radium C. Since gamma radiation is given off without intermission, whereas Roentgen rays were assumed in the foregoing to be emitted for eight hours a day, the tolerance dose must be reduced to $1/3 \times 10^{-5}$ r/sec. The radiant energy of the gamma radiation of 1 gr. of radium is thus small compared with the radiation of a Roentgen tube operating under normal conditions. It follows that the range of the gamma rays (up to the allowable intensity of $1/3 \times 10^{-5}$ r/sec.) is comparatively short, whilst their great power of penetration at short ranges makes very thick lead screening necessary.

Graph II will show that an X-ray tube operated with 1,000 kv and 1 ma would require to be protected with 17 cm. of lead if no injurious radiation is to be present at a distance of 50 cm. Since, according to what is stated above, the amount of gamma radiation given off by 1 gr. of radium represents about 1/50 ma, the thickness should be reduced by $\frac{2{\cdot}3}{\mu} \log 50 = 7.3$ cm. A protective casing about 10 cm. in thickness is thus required.

The international provisions lay down rules for protective measures in the case

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[1] Cf. *Hdb. d. Physik.* published by Geiger and Scheel, Volume 23, page 425, 1926.
[2] R. Ledoux-Lebard et A. Dauvillier, *Physique des Rayons X*, Paris 1921, p. 20.
[3] *Philos. Mag.* 35, 129, 1927.
[4] *Probleme der Gammastrahlung*, published by Vieweg und Sohn, Brunswick, 1927, p. 104
[5] *Hdb. d. Physik*, Volume 22, page 217, 1926.

of radio-active substances, but they give no information as to the distances at which the specified thicknesses of lead afford adequate protection.

Graph IV shows the ranges of gamma rays beyond lead screens of various thicknesses for quantities of radium ranging from 10 mg. to 10 gr. In accordance with what has been said above, the range is defined as the distance from the source of radiation at which the dose output of radiation begins to be smaller than $1/3 \times 10^{-5}$ r/sec. It is found, for instance, that, with a lead casing 5 cm. thick, the injurious radiation of 100 mg. of *Ra* element is operative within a radius of 64 cm. Without any protective screening, the gamma radiation of 100 mg. of *Ra* has a range of 2.40 m. in all directions. The normal filtering of the preparations has but little effect, since, in 1 mm. Pt. for instance, gamma radiation is only attenuated by approximately 9 per cent.

Whilst the radiation of a Roentgen tube, operating with 200 kv and 10 ma, and screened with 1 mm. Pb, has a range of about 20 m. (Graph III), the gamma radiation of 1 gr. of radium screened with 1 mm. Pb only has a range of about 7 m. ; if the screening of the Roentgen tube is brought up to 5 mm., the range is reduced to about 60 cm. in the case of 1 gr. *Ra*, on the other hand, the range is only shortened down to about 6.5 m.

If "absolute protection" is required — that is to say, if no injurious radiation is to be present even in immediate proximity to the protective casing — the thickness of the screen must be equal to the range. The corresponding thickness will be found, in Graph IV, along the practically horizontal curve *a-b* at the bottom. For instance, the Pb thickness required in such a case for 1 gr. *Ra* is about 14.8 cm., for 100 mg. it is about 11.5 cm. The range of 1 gr. of *Ra* on the far side of a 2.5 cm. protective screen is still about 4 m., whilst that of 100 mg. *Ra* is about 1.1 m. The best form of protection is hence distance from the source of radiation.

Comparison with the thicknesses of lead laid down in the international provisions shows that the latter provide for somewhat thicker screens:

Quantity of Ra element	International provisions	Values obtained from Graph IV
0.5 grms.	15 cm. lead	14 cm. lead
1.0 ,,	16.5 ,, ,,	15 ,, ,,
1.5 ,,	17 ,, ,,	15 ,, ,,
2.0 ,,	18 ,, ,,	16 ,, ,,

If, as was done above, the gamma-radiant-energy of 1 gr. of *Ra*, i.e., 8.6 calory hours, is taken as a basis, and if, the allowable residual of radiation being set at $1/3 \times 10^{-5}$ r/sec., it is desired to secure absolute protection in the sense already defined, values of lead thickness similar to those recommended in the international provisions will be obtained if an absorption coefficient of about 0.46 cm, is applied. So small a value could only apply to very hard components of the mixture of gamma rays, which are only present at low intensities; the regulations in the international provisions relate, however, to establishments for the extraction of emanation from radium solutions — that is to say, to fixed installations in which increased protection from radiation does not hamper the manipulative processes and can only be useful.

As regards the storage of radium salt, it is recommended, on the other hand, that the radium should be stored in a safe as distant as possible from the personnel. The radium tubes or applicators are, moreover, to be inserted into separate lead blocks giving a thickness of protective wall amounting to 5 cm. of lead per 100 mg. of *Ra* element. Graph IV indicates that the range of 100 mg. *Ra* screened with a protective wall of 5 cm. of lead is about 64 cm. If several such lead blocks, containing 100 mg.

of *Ra* each, are stored together, the reach is, of course, proportionately extended, so that, in an unfavourable direction, it is 90 cm. for 200 mg., and so on.

A separate room is to be provided for the " make up " of applicators. Lead screens of not less than 1 inch thickness are to be used (see above), and proximity to the radium is only to occur during actual work and for as short a time as possible. The measuring room is to be a separate room and should contain the radium only during its actual measurement. Assistants are not to remain in the same room as patients undergoing radium treatment. The persons engaged in " making up " applicators are not to be engaged on such work for periods exceeding six months.

Similar regulations will be necessary for institutes in which radium preparations are put up in containers, radio-active luminous paints are prepared, etc.

For the despatch of radium preparations by post regulations have also been laid down in the international provisions. It is stated that in the case of small quantities the container should be lined throughout with lead not less than 3 mm. thick and that it is more satisfactory to transport large quantities by hand in a suitably designed carrying-case.

In my opinion, 3 mm. of lead protection will serve no very useful purpose, since it attenuates gamma rays by 20 per cent at the outside. Better results would be secured if the preparations were placed, not only in a lead container of a thickness to be graduated according to the radium contained, but in the middle of fairly bulky packing so that a certain factor of distance would be introduced. In addition to that, a declaration of contents should be required, since it must be borne in mind that, apart from considerations of protection for the post office staff, other packages which may happen to be brought into proximity with radio-active substances are liable to be damaged thereby, e.g., photographic plates.

Precautionary regulations are especially necessary in connection with the use of emanation, since the gaseous emanation, on breaking down, leaves a radio-active deposit which may gradually exert destructive effects, on the skin for instance ; the inhalation of large quantities is injurious, and premises, measuring instruments, etc., may be " infected " by emanation. The international provisions, therefore, specify that the radium solution should be stored in lead containers of the previously specified thickness in a special room which should only be connected with the pumping-room by a tube. Rooms should be ventilated with an exhaust fan, and rubber gloves should be worn.

So far as the protection of adjacent rooms is concerned, it can only be adequate in this case, as distinct from that of X-rays of normal hardness, if the twofold precaution is taken of maintaining an adequate distance from the source of radiation and of casing the latter in lead. Owing to the low lead equivalence of masonry, protection by the latter is hardly worth considering. Particulars of the distances that must be maintained in order to keep adjacent rooms free from injurious radiation will, again, be obtained from Graph IV.

8. *Protective Measures in the Case of Other Kinds of Radiation.*

Protection is also necessary against the beta rays of radio-active substances. The beta rays are endowed with considerable kinetic energy; their power of penetration is consequently small; and this is the reason why they are only able to produce very superficial, though very extensive, effects, on the human skin for instance. Owing to their low power of penetration, protection is comparatively easy to provide. We are only concerned, here, with very slightly filtered radio-active preparations, and with the naked glass capillary tubes loaded with emanation. The best form of protection, here again, is the greatest possible distance. The preparations should therefore not be carried in the hand but should be manipulated with forceps, preferably made of wood, and carried from place to place in long-handled containers. The last-named precaution applies to gamma-ray preparations as well.

The cathode rays also fall under this heading, since they are similar in nature to beta rays and can now be produced with considerable energy values by high-output tubes with Lenard windows. Though their use for medical (therapeutic) purposes and in technical processes (e.g., sterilisation) is still in the initial stages, they may be utilised on a wider scale in the course of time. The cathode rays produced with high voltages approximate, in respect of their kinetic energy, to the beta rays of radio-active substances, and give extraordinarily powerful, even though comparatively superficial, biological effects. Owing to their low power of penetration protection is a comparatively simple matter — glass screens and the like, for instance, being sufficient. The simultaneously generated X-rays should, however, also be taken into account.

Special protective measures against alpha rays need hardly engage our attention, since they are absorbed by very thin casing and reach but a short distance through the air.

In the case of ultra-violet rays (artificial sunlight, analysis lamps, etc.) the precautionary measures may be limited to protection for the eyes; regulations concerning measurement and dosage would, however, be very welcome in the case of ultra-violet light as well, since, here again, injuries may be inflicted by overdoses.

9. *Protective Measures against Scattered X-Rays.*

So far, the observations made have reference to direct radiation, the primary radiation as it leaves the target of a Roentgen tube or a radio-active preparation. It is screened off so far as possible by the tube holders, protective cylinders, lead casings, etc., and narrowed down to the particular cone of radiation required for the purpose in view.

Apart from these casings, protection must hence also be provided to arrest the applied radiation after it has passed through the patient, through the product to be examined, etc. For this purpose, a protective screen must be mounted behind the radiated substance (behind the patient). In therapeutic radiation, sheet-lead is placed under the treatment bed, or the patient is laid upon a thick slab of lead rubber. In screening examinations, the fluorescent screen must be covered with lead glass of adequate protective value, whilst, in X-ray photography, the Roentgen cassette is usually provided with a metal bottom. The thickness of the protective material must be adjusted to the power and penetration of the rays.

All bodies on which short-wave radiation impinges are known, however, themselves to give off radiation consisting of electronic radiation, fluorescent radiation and scattered radiation. The first two kinds of radiation may be disregarded so far as protection is concerned. Not so, however, the scattered radiation, which may be quite considerable in certain circumstances. Scattered radiation must again be subdivided into two kinds, the classical, and Compton's scattered radiation. The former consists of primary radiation which has merely been deflected from its original path, the latter, however, of rays which have simultaneously undergone an increase of wave length. The classical scattered radiation predominates in the case of soft Roentgen-rays, Compton's radiation in the case of short-wave X-rays and gamma-rays. So far as protection against radiation is concerned, the increase of wave length may be disregarded.

The strength and power of penetration of scattered radiation depends upon the intensity and quality of the primary radiation and on the nature and volume of the scattering substance; to this must be added a powerful directional factor which also varies with the quality of the primary radiation. The problem of scattered radiation is hence highly intricate and does not lend itself to mathematical treatment. Investigations must therefore be based upon the results of experiments carried out under suitably selected experimental conditions.

The dependence of scattered radiation on the quality of the primary radiation is of such a kind that, in the tissues of the human organism — which are the principal scattering medium concerned — the intensity of scattered radiation is at its maximum, more or less, in the zone of roentgentherapy radiation, whilst it drops appreciably both with very soft and very hard radiation, as has recently been demonstrated in some detail by GUNSETT and NOURETTINE O. [1] So far as the gamma rays of radium are concerned, scattered radiation is of minor importance, seeing the intensity of the gamma radiation is comparatively small. Discussion may therefore be limited to X-rays.

In this connection, we have the work of SCHLECHTER, [2] SCHEFFER, [3] FRICKE and BEASLEY, [4] JACOBSON [5] BEHNKEN [6] and my own measurements.

SCHLECHTER's investigations relate to medical X-ray diagnosis. He finds that, generally speaking, the secondary radiation, which originates in the patient's body, the walls and objects in the room, largely predominates over the primary radiation as attenuated by the usual protective casing of the tube. In the places where the doctor and the assistants usually stand during screening examinations, dose outputs rising to 50×10^{-5} *r*/sec. were found, whilst behind the tube the values ranged up to 800×10^{-5} *r*/sec. It is hence necessary, first, to surround the tube with a protecting cover which only allows a limited applied cone of radiation to emerge, and the thickness of which should be determined in accordance with the standards governing protection against direct radiation. Secondly, the patient must be screened off in all directions with strips of lead rubber curtain, which may be hung from the stand and the fluorescent screen, when the patient is in the standing position. By this means, the radiation in the doctor's position was reduced to less than 1×10^{-5} *r*/sec., whilst, at the back of the tube, the radiation emerging from the patient amounted, at a distance of 70 cm., to 8-15 $\times 10^{-5}$ *r*/sec. At a distance of 3 m., the radiation, in this place too, fell below 1×10^{-5} *r*/sec. In order to protect the examiner's legs and feet a further device is recommended, which is known in Germany as a "Schutzkanzel protective pew". The protective glass in front of the fluorescent screen must satisfy the requirements for protection against direct radiation.

In medico-diagnostic work, as already mentioned, the standards of protection to be laid down can be somewhat lowered because the apparatus is not in constant operation, intervals always occurring between periods of ray production. On the other hand, it must be remembered that, in X-ray photography, exposures are only very short, although admittedly high energy values are frequently employed. To this must be added that, in the case of photographs at a distance, long stretches of intervening air are irradiated, and even though the scattered radiation of the air is but small, yet it must not be disregarded in this connection. [7] It will be desirable in any case, in medico-diagnostic installations, either to place the control table in a special room or to move it as far away as possible from the tube, behind a protective partition of about 1 mm. lead equivalent.

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[1] *Journ. de Radiol.*, 14, 551, 1930.
[2] *Fortschritte Röntgenstr.*, 34, 946, 1926.
[3] *Strahlenth.*, 22, 726, 1926.
[4] *American Journal of Roentgenol.*, 18, 146, 1927.
[5] *Ibid.*, 18, 149, 1927.
[6] *Fortschritte Röntgenstr.*, 41, 245, 1930.
[7] RUMP : *Fortschritte Röntgenstr.*, 38, 58, 1928.

Technical diagnostic work, the examination of materials and the like, differs in this respect from medical work, in that large quantities of energy are used for prolonged periods. In this case the conditions to be fulfilled must be those laid down for medico-therapeutic radiation.

In therapeutic Roentgen radiation (180 kv, 6 ma, 0.6 mm. Cu. filter, 10×15 cm. field, 40 cm. target-skin distance) with a protected tube and a phantom, Scheffers (*op. cit.*) found, where the phantom is not enclosed and where no underneath lead protection is used, a dose output of 800×10^{-5} *r*/sec. on the floor directly below the patient — that is to say, directly in the cone of radiation — and 900×10^{-5} *r*/sec. in close proximity to the patient's side, whilst, when a belt-shaped lead protector of 3 mm. Pb is used, the corresponding values work out at 0.1 and 0.2×10^{-5} sec. respectively. Where no protective belt was used and the beam of radiation was not screened (no "cone" being mounted), the value at 1.5 m. distance from the cone of radiation was about 16×10^{-5} *r*/sec., whilst when a protective belt and a " cone " were used, it was about 0.4×10^{-5} *r*/sec.

Behnken's measurements (*op. cit.*) relate to the Media-Metalix and the Metwa-Metalix protective tubes used in conjunction with a phantom. The Media-Metalix tube was operated with 75 kv, 4 ma and 0.5 mm. Al filter, that is to say, under the conditions of ordinary medical X-ray diagnosis. With an unenclosed phantom and no "cone", dose outputs of $15\text{-}20 \times 10^{-5}$ *r*/sec. were measured at a distance of 1.5 m. When the phantom was enclosed in 1 mm. of sheet lead, and a lead glass "cone" was used, the radiation dropped to about 0.2×10^{-5} *r*/sec. The Metwa-Metalix tube was operated under conditions (200 kv, 3.5 ma) corresponding to hard therapeutic radiation. With an unprotected phantom, but with a lead glass "cone" mounted, the dose output was $30\text{-}40 \times 10^{-5}$ *r*/sec. at a distance of 1 m. and, in the immediate vicinity of the phantom, as much as $1{,}000 \times 10^{-5}$ *r*/sec. It was found that adequate protection could be obtained even for persons remaining in immediate proximity to the phantom by using 2 mm. of lead protection.

The experiments so far described were all performed with the help of phantoms. I myself have taken a series of measurements during normal therapeutic radiation of patients. The Roentgen tube was surrounded with ray-proof casing on all sides (Wintz mounting). The conditions of operation were respectively 200 kv, 3 ma, 0.5 mm. Zn + 3 mm. Al filter on the "Symmetrie" apparatus, and 200 kv, 15 ma, 0.5 mm. Zn + 3 mm. Al filter on the transformer therapeutic apparatus. The patient was either not covered, or protected with a belt of lead rubber 6 mm. in thickness, which only exposed the field of radiation (abdomen). Experiments were carried out both with a radiation "cone" placed on the body and without such a "cone", at focal distances of 30 and 90 cm. The results are set forth in the following table :

Case	Tube current	Target-skin distance	Field	Protection of patient with lead rubber	" cone "	Dose output at a distance of 1 m. from the patient
1.	15 ma	90 cm.	15×15	Yes	No	$50 - 55 \times 10^{-5}$ *r*/sec.
2.	15 ma	90 cm.	15×15	Yes	Yes	$5 - 10 \times 10^{-5}$ *r*/sec.
3.	3 ma	30 cm.	8×8	Yes	Yes	$0{,}7 - 2 \times 10^{-5}$ *r*/sec.
4.	3 ma	30 cm.	8×8	No	Yes	$3 - 10 \times 10^{-5}$ *r*/sec.

The measurements were taken, with a special ionisation chamber, at a distance of 1 m. from the cone of radiation and at a height of 1 m. from the floor, both at the patient's head and feet and on both sides. The figures show that only in Case 3 — that is to say, where the lead-lined radiation "cone" is placed on the field of radiation and the patient is thoroughly covered with lead rubber, is it possible to remain continuously at a distance of 1 m. with the low tube current of 3 ma. A comparison between Cases 2 and 3 will show that, with 5 times the tube current, the scattered radiation is also about 5 times as great. Case 1 indicates the powerful scattered radiation which is given off backwards from the radiated field if a "cone" extending right down to the patient is not used ; in this case there is the added scattered radiation of the air. Case 4 shows, by comparison with Case 3, the scattered radiation which is given off sideways from the patient.

These experiments show the desirability, in all cases, of keeping the control table as far as possible from the tube and of placing it behind a protective partition. A calculation with $\mu = 20$ (see Graph I) shows that the most powerful scattered radiation measured can be reduced below 1×10^{-5} *r*/sec. by a protective partition of 2 mm. of lead ; to this must be added the effect of the distance, which is doubtless 2 m. at least in all cases. The protective value of a window in the lead partition must obviously be equivalent to that of the partition itself.

It might be objected that the tertiary scattered radiation engendered by the scattered radiation in the walls and floor of the room can get behind such a protective partition ; measurements showed, however, that in no case was a dose output of 1×10^{-5} *r*/sec. attained behind protective partitions of 2 mm. of lead. In order to minimise the radiation emitted by the partition, some regulations provide that the latter should be arranged as close as possible to the wall of the room. Fricke and Beasley (*op. cit.*) and Jacobson (*op. cit.*) found that even with tubes but inadequately protected with lead glass bowls, the dose behind a protective lead partition only had a conversion value of $1\text{-}3 \times 10^{-5}$ *r*/sec., whereas the measurements taken in front of the protective partition gave $80\text{-}100 \times 10^{-5}$ *r*/sec.

The conclusion to be drawn from the above is that the requirement of a separate ray proof room for the service of the Roentgen apparatus in medical work can be dropped, provided the tube is enclosed in a ray-proof casing or affords adequate protection by itself. Even in unfavourable cases, a lead partition of 2 mm. thickness suffices to render harmless the scattered radiation given off by the patient. The presence of the X-ray assistant in the radiation theatre itself is desirable, not only on psychological grounds in the interest of the patient, but especially because much more reliable supervision of the protective screening is thereby secured. The placing of a ray-proof substance underneath the patient and the covering of the patient with lead rubber over a wide area round the field of radiation should always be made a rule in order to reduce scattered radiation.

If the regulations already issued in a number of countries are examined in the light of the above considerations, it will be found that measures have in some cases been demanded or recommended which must be regarded as extraordinarily far-reaching.

Where the tube is insufficiently protected, the operator's room had best be separated from the radiation theatre. The German regulations provide that, with tensions below 125 kv, persons may be employed in the theatre if a protective partition with side wings, measuring at least 2×2 m. (inclusive of the side wings) and having a lead equivalent of not less than 2 mm. is provided for their protection. The protective partition is to be placed as far away as possible from the tube (at least 1.5 m.) and as close as possible to one of the walls. Where the tension exceeds 125 kv and the tube protection is inadequate, all regulations doubtless provide for a separate operator's room with suitable ray protection. To this, no objection can be raised but to stipulate, like the Russian regulations, for a protective cabin or separate rooms with walls of up to 6 mm. lead equivalent, where a built-in ray-proof tube is used, must be regarded as an exaggeration. In my opinion, as already explained, the presence of the assistants in the treatment room itself is indeed a desideratum, though of course they should only remain in places where complete protection from radiation is provided. If the tube is built in in such a way as to be ray-proof, such protection can be obtained, under ordinary conditions of radiation, by a protective partition of 2 mm. of lead at the outside.

10. *Tests for the Soundness of Ray-proofing.*

A method has been set forth in this survey whereby it is possible to determine from the sets of curves reproduced, whether, given the usual conditions in respect of tension, tube current, distance and thickness of protective material, a particular spot is a suitable place for the human organism to remain in indefinitely without fear of injury. Such curves offer a particularly suitable means of determining whether the proposed protective measures in new installations will be sufficient. In the case of existing establishments it is possible, on the other hand, to ascertain the dose delivered at a particular spot by direct measurement.

The methods of mensuration utilised for the purpose must be capable of detecting small amounts of radiation. Such methods involve the use of the photographic emulsion, the fluorescent screen and ionisation.

For this purpose, Eggert and Luft [1] have given particulars of a very handy Roentgen film-dosimeter that can be carried in the pocket, and contains a film. When the latter is developed, the quantity of Roentgen radiation to which the bearer has been exposed for a certain time can be inferred from the visibility of certain marks. The dosimeter has been designed for qualities of radiation such as occur in medical X-ray diagnosis; my experience has been, however, that it can also be used for deep therapy rays when suitably calibrated.

Bouwers and van der Tuuk [2] have also developed a photographic method which is based, for soft rays, on the measurement of the blackening of a film, whereas, for hard rays, the different permeability of copper and aluminium is used as a criterion.

Another method, which has frequently been described, involves the use of a fluorescent screen (Willemite). In this connection the international provisions read as follows : " It should not be possible for a well-rested eye of normal activity to detect in the dark appreciable fluorescence of a screen placed in the permanent position of the operator ". To this statement, Bouwers and van der Tuuk (*op. cit.*) raise the objection that, according to experiments performed by them, the fluorescence of the screen at a distance of 1 m., with a tube current of 4 ma and lead protection corresponding to the specifications of the international provisions, does not necessarily prove that there is really any danger to be apprehended.

Glocker and Reuss [3] reach a similar result, but state, in conclusion, that the fluorescent screen test can be used as a simple and expeditious method of approximation for the determination of the tolerance dose, provided that allowance is made for the considerable inherent margin of error (which resides mostly in the varying sensitiveness of the human eye). This presupposes that the allowable dose has been fixed at the same value both for diagnostic and therapeutic radiation ; if, however, in

[1] *Röntgenpraxis*, 1, 188 and 655, 1929.
[2] *Fortschritte Röntgenstr.*, 41, 767, 1930.
[3] *Fortschritte Röntgenstr.*, 42, 651, 1930.

accordance with the German rules for protection against radiation, a higher dose is allowed in diagnostic work than in therapeutic work, the fluorescent screen test can only be used in therapeutic establishments.

The most suitable method for exact measurement is undoubtedly the ionisation method, if allowance is made for the numerous sources of error attaching to this method as well. In this case, use is made of large-sized chambers permeable on all sides, as described, for instance, in cylindrical form by Fricke and Beasley [1], and in spherical form by Behnken. [2]

It would be desirable for X-ray establishments of all kinds to be subject, in regard to the adequacy of ray-proofing, to regular compulsory supervision, which might be entrusted to the institutions responsible for the standardisation of X-ray doses.

11. *Dangers caused by Valve Tubes.*

Incandescent valve tubes have latterly been used on an increasing scale for the rectification of the secondary voltage of transformers and induction coils. They are similar in design to the Coolidge tubes, with the sole difference that the concentration of the cathode rays on a more or less extensive focal spot of the anode is avoided. It is obvious that, in these tubes also, the impact of the cathode rays on the anode engenders X-rays ; it is asserted, however, that the voltage drop in the valve is so slight, and that the Roentgen rays are consequently so soft, that they do not penetrate the glass wall of the valve. This is especially true if the heating of the incandescent cathode of the valve is adequate. This is the point to which the German regulations refer when they state that " care must be taken to comply with the particulars concerning heating as set forth in the manufacturer's instructions ".

It has recently been found, however, that, when the Roentgen apparatus is connected up in certain ways to the valve tube, then, notwithstanding adequate heating of the cathode, a considerable loss of voltage occurs, which manifests itself in the glowing of the anode in the valve. In such a case considerably harder Roentgen rays are generated, which pass through the glass wall and may be dangerous to the persons operating the apparatus.

Whether 0.1 or 0.2 mm. Pb, as laid down in the Czechoslovak regulations, are sufficient to screen off this radiation, would appear doubtful. In this case, it would be desirable, as recommended by the Austrian proposals, to apply, *mutatis mutandis*, the regulations governing protection from direct radiation by the Roentgen tube.

The increase in the voltage drop of the valve tubes has been ascribed to the charging of the glass wall. By special designing it has been possible to eliminate this defect, which may affect the reliability of the voltage measurement and the dosage, by constructing the body of the valve of metal (Philips-Müller [3] Metalix valve) or by surrounding the discharge chamber within the glass with a metal cylinder. [4]

In any case, it is desirable to make certain, by means of a fluorescent screen, used in the manner described above, that the valve is emitting no X-rays.

B. Measures for the Protection of the Patient.

Regulations designed to protect the patient from injury by rays must cover a multitude of different points. The object is not merely to provide protection against

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[1] *American Journal of Roentgenol.*, 18, 146, 1927.
[2] *Fortschritte Röntgenstr.*, 41, 245, 1930.
[3] Vierkötter : *Fortschritte Röntgenstr.*, 42, Congress Edition, 143, 1930.
[4] Hofman : *Ibid.*, 147, 1930.

inadvertent radiation, but also to safeguard the patient against an overdose of rays, and, finally, against inadequate radiation — that is to say, against unsuitable or injurious treatment. Generally speaking, the radiation concerned in this connection is that of X-rays.

1. *The Avoidance of Inadvertent Direct Radiation.*

Protection from inadvertent radiation is mostly a technical matter, and is closely linked up with the measures for the protection of persons employed in X-ray establishments. A distinction should, however, be made to this extent, that the patients usually remain (but for a short time) within range of the radiation. The primary object is to ensure that the patient's body is only exposed to the radiation at the places requiring to be radiated for purposes of examination or treatment. The remainder of the body must not be subjected to the rays to any appreciable extent, and certainly not to quantities of radiation exceeding those delivered by the applied cone.

Especially with the older type of narrow tube holders, which were made of wood and surrounded with lead rubber, it frequently happened that the protective material became split or torn, thus occasionally letting through unfiltered direct radiation which might impinge upon the patient's body. This produced strip-shaped burns. Such a defect can be easily detected. In order to test holders for the soundness of the protective material, I use a small fluorescent screen shaded from the light and mounted at the end of a Pertinax tube which is fitted with an eye-piece, a so-called fluorescent tube of the kind that can be used with advantage to determine the boundaries of the cone of radiation in distant field work.

The old tube holders referred to, as well as the lead glass bowls, allow unfiltered radiation to pass at the point where the arms of the tube emerge, and this may in some cases impinge upon the patient's body. It has therefore been laid down — as, for instance, in the German regulations — that such tube holders must be set in such a way that the longitudinal axis of the Roentgen tube is at right angles to the longitudinal axis of the patient's body. A fresh danger then arises, to be sure, in regard to the high voltage, since the patient is now able to grasp both ends of the tube simultaneously with his hands.

2. *Safety Measures in Connection with Filters.*

One mistake, which is difficult to deal with and has already been responsible for many an injury to patients, is the inadvertent omission of the filter or use of the wrong filter. Innumerable proposals have already been made as to the way in which such an oversight may be prevented, without any ideal solution having been devised.

It is comparatively easy to imagine devices which would prevent the omission of the filter. In primitive X-ray installations in which the high tension feeds are connected to the tube with simple hooks, both the end of the high tension lead to the anticathode and the electrode connection of the tube have been formed into a loop, so that they cannot be joined up without further ado. For this purpose a double hook is necessary, which is fixed by a tape to the filter. With the modern protective casings, this method can no longer be used, since the tube is not readily accessible. In this case, the filter safety device has been combined with an obturation shutter. The latter is non-permeable and closes the radiation aperture ; it is provided with a stop catch that can only be released by the insertion of a filter. The radiation aperture can hence only be opened if a filter is mounted.

Such devices doubtless provide against the omission of the filter but not against the use of the wrong filter. In order to prevent this, the several filters have been provided with various projections operating an electrical indicator on the control table when the filter is inserted, so that the operator at the control table can see which filter is being used. The mechanism must, in the nature of things, be highly intricate and is hence liable to give trouble, apart from the fact that it does not prevent the administration of a dose incommensurate with the filtering used. In the case of incandescent cathode tubes, which are now used almost exclusively, the safety device can also be introduced into the filament circuit. Thus each filter may be connected by a tape to a plug which must be used to close the filament circuit before X-rays can be generated. In that case, each filter is attached to a specially shaped plug which can only be used if the doctor in charge has perforated a card in such a way that the plug belonging to the requisite filter can be inserted.

In my opinion, the simplest method is the best, since experience has shown that complicated equipment is not used in the long run. For years I have been using with great success small plates which are fastened to the filters by tapes ; a special colour is used for each filter metal (Cu. red, Zn black, Al white) and for each strength of filter a special shape of the plate (round, angular). In this way, it can be seen from a distance which filter is being used.

The best solution, as such, of this filter problem is that either the dose or the dose output should be simultaneously measured during radiation. For this purpose use may be made of dose-recording instruments such as Strauss's Mekapion or the Hammer dosimeter, and for the second type of measurement, the Siemens' Roentgen dosimeter or large-size chambers in the funnel with galvanometer reading. When dosimeters are used, an appliance can be fitted which switches off the tube as soon as the allowable dose has been administered. The method of dose recording has only been developed in recent years ; it remains to be seen whether the instruments will prove efficient in practice. The use of such an instrument involves a considerable complication of the X-ray apparatus, especially if no hard and fast method of radiation is adopted, but focal distance, size of field and " cone " are adapted to the requirements of each case. The usual consequence is then that the instrument is not used. In any case, even if a dose recorder is used, it is desirable that each filter and combination of filters should be provided with a distinguishing mark which is visible from afar.

At this point, a word may be said as to the protection of the patient from injury caused by the breaking of the Roentgen tube. So-called dry tubes are now being widely used, in which the Wolfram anti-cathode becomes white hot during operation. The glowing anti-cathode might hence possibly fall on to the patient, if the anti-cathode stem should break during radiation. For this reason, in the Norwegian regulations, for instance, a clause has been included providing for the insertion of an asbestos plate between the tube and the filter. Such an accident can only occur in very rare cases, and it is improbable that the anti-cathode could melt its way through an ordinary filter.

This precautionary measure, which was almost universally adopted at the time of the introduction of Coolidge tubes, has therefore since been dropped and may doubtless be regarded as superfluous. So far as the widely used plate-shaped anti-cathodes are concerned, their heat capacity being small and the stem in the tubes concerned being less brittle, such an accident is doubtless wholly impossible, provided always that a filter of some kind has been mounted. Where hot-water cooling is used, the breakage of the water jacket, which is frequently made of glass, may lead to the scalding of the patient ; the use of metal water jackets is hence recommended.

Formerly, the possibility of injury to the patient by the characteristic radiation of the copper or zinc filter was also feared. In order to obviate this danger, a combination with aluminium was used, that was fitted in front of the copper or zinc filter, in the direction of the patient. The characteristic radiation of the heavy metals is thus absorbed by the aluminium, whilst the characteristic radiation of the aluminium itself is so soft as to be absorbed in a thin layer of intervening air. Latterly this precautionary measure has been largely dropped since the intensity of the characteristic radiation is very small, and since, in close-range radiation, a " cone " is commonly used, the bottom plate of which is sufficient to cut off such radiation.

3. *Reliability of the Measuring Instruments.*

In the majority of radiation establishments, the practice of dosing " by time " still prevails. In this case, the dose output or the dose under specified conditions of tube voltage, tube current, filtering, focal distance and size of field, is determined by preliminary calibration. From this, the length of exposure required for a particular case is computed, and the radiation itself is measured with a watch.

In order to deal exhaustively with this matter, it would be necessary to discuss the whole of the dosage problem ; for present purposes, it will be sufficient, however, to deal with the major points so far as they lend themselves to regulation on general lines.

In radiation by time, it is necessary that the conditions under which the calibration took place should be reproduced during actual radiation. Reliable electrical measuring instruments must consequently be used. The measuring instruments concerned are the so-called kilovoltmeter (or tension meter) and a milliampèremeter, the former being used to determine the tube voltage, the latter the tube current.

As a rule, voltmeters are not used in the high tension circuit ; the usual practice being to infer the tube voltage from the readings of a voltmeter which is placed at the ends of the primary winding of the transformer (or induction coil). Since the relation of secondary voltage to the primary voltage depends upon numerous factors and is particularly influenced (more especially in the case of induction coil apparatus and continuous current apparatus with condensers) by the load of current in the tube, and is liable, moreover, to be changed by spark gaps (rectifiers) or incandescent valves, careful calibration of the primary circuit voltmeter relatively to secondary voltage is essential — that is to say, the X-ray output or dose must be determined in relation to the deflection of the voltmeter needle at various loads, by calibration with a dosimeter. The voltmeters commonly used on the primary circuits are soft iron instruments; they are standard technical instruments with good damping. They rarely cause trouble.

The most important instrument in the high tension circuit is the milliampèremeter, which gives a direct measurement of the tube current. Revolving coil instruments with a special winding are used for this purpose. In certain circumstances, owing to the effects of the high tension, the winding may be burned out ; in order to prevent this, a condenser is connected up in parallel. Since such defects may result in wrong readings, it is advisable to connect up two milliampèremeters, one behind the other ; the German regulations, for instance, stipulate for this. Wrong readings may also be caused by electric charging of the covering glass. This must be prevented by covering the glass as adequately as possible with metal or wire gratings, rubbing in glycerine or the like.

In induction coil apparatus (especially where continuous current is used) the frequency of the interrupter must be tested and kept constant.

Special attention should be given to the measurement of time in radiological work. The old practice of using the cheapest alarm clocks must be deprecated. At least two reliable time-pieces should be used for every X-ray tube. They should, for preference, be fitted with a stop-watch device which can be easily operated and should be used during temporary interruptions of the radiation. The end of the period of radiation should be recorded by a signal. Such chronometers can also be made to operate automatically and can be provided with a recording device; the switching off of the apparatus at the end of the period of radiation can also be effected by the chronometer. [1] In addition to such an automatic chronometer, which may fail to act, a second watch should also be used.

Dose measurement during calibration is nearly always carried out with a stop-watch. Since the period of radiation is generally a high multiple of the time measured off in this way, it is important that the radiation chronometer and the stop-watch should be going at the same rate. Even where dosimeters are employed during the period of radiation, it is desirable to use a watch in addition.

All the instruments mentioned must be most carefully watched during the whole period of radiation. It is hence necessary to have, for every radiation theatre or for every radiation set, a properly trained staff to adjust the controls throughout the period of radiation; the operator should not be allowed to leave the control table until the Roentgen tube has been switched off and the watch has been stopped. The staff must not be allowed to engage in other occupations, such as reading and the like, whilst radiation is going on.

4. *Training of Medical Attendants and Assistants.*

Apart from the requirement that careless errors of dosing through the omission of the filter, or use of the wrong filter, through maladjustment of the testing instruments, through incorrect measurement of the distance, wrong time measurement or the like must be avoided ; the most important stipulation for the protection of the patients in therapeutic work is that the right dose shall be administered. The patient is entitled to demand, not only that injury by overdosing shall be avoided, but also that he shall not be given too small a dose which would merely give him the illusion of effective treatment, and might, in certain cases, jeopardise his chances of a cure. In the outside world, to be sure, failure does not arouse so much attention as the infliction of burns.

The correct use of radiation can only be guaranteed if the practice of radiotherapy is only permitted to such qualified doctors as have undergone the necessary specialised training. In this connection, grave abuses still prevail in many countries, but a settlement of this question by general regulation is hardly practicable ; in most cases, indeed, it is left to the representative bodies of the medical profession to determine what conditions must be satisfied by a radiological specialist.

In Germany, proposals on the subject have been drafted by the German Röntgen-gesellschaft, with the object of instituting general supervision of X-ray establishments by the health inspection authorities. These proposals stipulate that the use of Roentgen rays in all branches of medicine should only be permitted to X-ray specialists. By X-ray specialists is meant qualified doctors who can show that they have undergone three years' training under the direction of a recognised medical X-ray specialist. A twelve months' course would be required for training in particular branches of X-ray application and a six months' course for training in a narrowly circumscribed field of specialist work. Supervision would be exercised by the competent medical authorities. Recently, in an agreement concluded between the German Medical Association and the Federation of Sick Funds, it has been stipulated that any doctor using X-rays must bring evidence before a Commission that he has had suitable training in the whole branch or in the special branch of roentgenology in which he is working.

Another problem which has frequently been discussed (by Holzknecht among others) but not yet solved, is the training of the medical student with a view to the

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[1] E. H. Müller, *Fortschritte Röntgenstr.*, 42, 657, 1930.

subsequent professional use of rays. Nowadays, there is probably no single medical man who does not, in some way or the other, have to deal with X-rays in his practice; but it happens only too frequently that he lacks the fundamental knowledge necessary for a proper understanding, not having acquired it in his student days. Lectures on the subject are, it is true, given at many universities, but experience shows that they are but poorly attended by medical students. The reason is simple, the medical student has already so much to do in his compulsory subjects that, only in the rarest cases does he feel any inclination to burden himself with further knowledge, the need for which is only realised later on. The references to the use of radiation, which usually occur as mere incidental allusions, in the medical lectures are generally but imperfectly apprehended, since the fundamental facts of roentgenology cannot be conveyed in this way, but must be assumed to be known. It is hence essentially desirable that the medical schools should give lectures and practical training in general radiology, and that this should be included in the examination subjects.

Once the foundations have thus been laid for a proper understanding of the action of short-wave rays, the dangers attaching to their employment and the precautionary measures to be taken, there will be an end of those cases — now so frequent and so widely feared — of incurable burns being inflicted at screening examinations through overstepping of the permissible dose. How often do we not find doctors who give therapeutic radiation, though incapable of carrying out a dose measurement themselves? There are also numerous instances in which radiation establishments, even in the larger hospitals, have the dose determined once and for all by a technical expert and then plunge forthwith into radiation on the basis of this one measurement. This shows a lack of understanding which can only be remedied by thorough training during medical studies.

This question of training in medical radiology was the subject of numerous reports to the Second International Congress of Radiology at Stockholm in 1928. No less than twenty-three countries took part in the discussion. The addresses given by their representatives have already been published as Supplementum IV of the *Acta Radiologica*, Stockholm, 1930, under the heading: " Teaching and Training in Medical Radiology ". The general conclusion to be drawn is that, whilst the desire is everywhere felt to give the medical student a certain grounding in radiology as a *vade-mecum* in his practical work, so far the efforts made to that end have had but a very slight measure of success.

One of the countries which has advanced farthest in this direction would seem to be Sweden [1] where, since 1928, compulsory general courses of 20 hours' study in X-ray diagnosis have been given to candidates for medical degrees by a regular professor of medical radiology. The object of this compulsory course is to introduce students to the science of the structure of the human body as it appears under X-ray examination. Instruction is given in the form of lectures with lantern-slide and X-ray photograph demonstrations. No examination is held. In addition to this, optional post-graduate courses are given, with the object of conveying a general idea of medical radiology and of affording facilities for some practical exercises in X-ray diagnosis and X-ray technique. Finally, special training in diagnosis or therapy is afforded by two or three years' probationer work as medical assistant at the X-ray institute of the university or of the large hospitals. The full course of radiology covering the whole of the ground usually takes from four to five years.

For the protection of the patient, proper training of assistants is also required. The latter may not undertake medical examinations, make diagnoses, draw up

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[1] Forssell, *Acta Radiologica*, Supplement IV, 145, 1930.

radiation charts, determine the dose, etc.; this is solely the business of the qualified doctor and radiologist; the assistants must, however, have a general idea of the structure of the human body, they must master the physical basis of dose measurement, they must be able to compute the dose for a particular case and must have experience in the controlling and adjusting of the various apparatus. Only if they have undergone adequate preliminary training, will they be able to give valuable assistance to the doctor and possibly safeguard the patient against danger in certain cases.

The extensive training thus required can clearly be provided only in large establishments, such as universities for example. In Germany, suitable courses are given at approved institutes, which provide for eighteen months' practical and theoretical study, on the conclusion of which an examination is held under State supervision; there follows six months' practical work, after which the State diploma is granted. The standards set at the examination are extremely high; it is hence all the more necessary that the roentgenologist should himself be adequately trained in order that he may be in a position to supervise the work of the assistants.

5. *Dosage Questions.*

The most essential safeguard for the patient lies in correctly performed accurate dosage, which should extend also to the diagnostic use of rays. Owing to the introduction of the international unit, dose measurement has been placed on a very much sounder footing in recent years, although it must not be overlooked that the choice of an ionisation unit as a basis has introduced a number of difficulties into the problem.

The mode of expression used in *r* unit dose specifications lacks that direct appeal to sense perception which has made the skin unit dose so widely popular; *r* unit dosage also lacks that natural upper limit which is set to the skin unit dose by the capacity of the skin. Owing to the realisation of this fact, demands have recently been made (1930, Congress of the German Röntgengesellschaft) for a dose unit, apart from the *r* unit, which will be more readily understandable by doctors than a mere numerical value. If the advocates of this measure proposed the term " tolerance dose " [1] this really amounts to nothing more than what has previously been termed the skin unit dose; for, in the course of years, the latter term has lost its original meaning as a strictly defined amount of radiation, and has only retained its biological meaning as the limit of tolerance of the normal human skin. When expressed in *r* units, this limit is known to be variable and changes with the intensity of the radiation (biological additional dose, time factor), so that, as the intensity is reduced and as the period over which administration extends is prolonged, increasing *r* values correspond to the skin unit dose for one and the same effect.

A further complication arises out of the fact that, at the present moment, it must be regarded as questionable, to say the least, whether the dose giving a particular biological reaction corresponds to one and the same value in *r* units with different qualities of radiation. The underlying idea in the introduction of the ionisation unit as the basis of dose measurement was that, the mean atomic number of the tissue substances on the one hand and of the air on the other being practically identical, the absorption of rays, and thereby the effect, would be likely to vary in the same way when the quality of the rays changed. In other words, when the dose was measured in *r* units, the effect would be independent of the quality of the radiation. Apart from

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[1] The expression " tolerance dose " is, as a matter of fact, already used to indicate a dose which can be absorbed indefinitely without injury.

the fact that, even theoretically, the mass unit absorption of air and tissue is not exactly the same and that the great difference in density must also be borne in mind, practical experience does not seem to bear out this view. For instance, in skin therapy, 600 *r* of primary radiation, which has been recognised as equivalent to the skin unit dose for purposes of deep therapy with medium qualities of radiation, is not commonly used. On the other hand, experience has shown that very hard Roentgen rays can be used in far higher *r* unit doses; and, where radium gamma rays are concerned, 500 mg.-element-hours at a distance of 1 cm. is almost universally regarded as equivalent to the skin unit dose (e.g., Friedrich, Mallet and Coliez, Gauss, Wintz, Glasser). Converted into terms of *r* units, this, however, works out at 2,000 *r* units, if the time factor is allowed for. On the other hand, attempts have, it is true, been made to prove by experiment that the same dose is necessary to produce a particular biological reaction whatever the quality of the rays; but these experiments have usually been performed only with small skin fields or small biological objects; it therefore looks as though the additional scattered radiation might be a factor of considerable importance.

These questions will doubtless be cleared up in the course of time; it would be desirable, however, that a decision be hastened by systematic enquiries carried on under a central authority.

A certain amount of confusion and difficulty in coming to a mutual understanding about dosage has, however, been caused by the introduction of the *r* unit, owing to the fact that the skin unit dose has been brought into relation with the corresponding output of (primary) radiation; thus in deep therapy radiation of medium quality, one skin unit dose = 600 *r*. The skin unit dose comprises, however, the additional scattered radiation for a specified size of field (6×8 cm.), so that the total amount of radiation which takes effect on the surface of the skin is really 800 *r*. Especially where the dose is measured with a dose-recording instrument (Hammer dosimeter, Mekapion) this frequently leads to underdosing.

Another controversial point is that of the unit of measurement or quality of radiation and homogeneity of radiation. The immediately intelligible unit of measurement for quality of radiation, which is indispensable to the practitioner, is the deep dose percentage, whilst more recently the half-value layer in copper or aluminium has been advocated. It would take us too far to go into the changes of quality which occur in the radiation, when the usual method of determining the half-value layer is adopted. Similarly, the ratio of two successive half-value layers, which has been proposed as a measure of homogeneity, is entirely unsuitable owing to the changes of quality involved.

All these questions might be suitably investigated by a central authority.

In any case, the introduction of an international dose unit has meant a considerable advance towards a general standardisation of dosage, and has thus brought the manifold problems of disease nearer a solution ; we must, however, strive to ensure that every radiologist is compelled to employ the unit dosage. Very little has, however, been done as yet in this direction. Thus, in an agreement recently concluded between the German Medical Association (Hartmannbund) and the Federation of Sick Funds, the following passage occurs:

> " Every deep therapy installation should have adequate measuring appliances which operate either on the ionisation or on the fluorescence principle. Sabouraud-Noiré dosage is out of the question in deep therapy. "

It is not enough, however, for a suitable measuring instrument to be available; it must also be used, and, above all, it must be reliably calibrated. This calibration, like the adjustment of balances, etc., must be regularly checked. For this purpose the various countries have set up standard departments which are provided with calibrated and regularly verified instruments by a central authority, such, for instance, as the Physikalisch Technische Reichsanstalt in Germany.

6. *Dosage in X-Ray Diagnosis.*

In medical X-ray diagnosis, conscientious dosing is also absolutely essential, as already mentioned. The Roentgenologist must know how long he can prolong a screening examination, and how many photographs he may take without risk of injury to the patient. For this reason, time measurement is especially important in screening examinations [1]. Experience shows that most of the burns sustained through the diagnostic use for X-rays are inflicted when the zest of observation leads inexperienced examiners to exceed the proper limit of time. The time-recording of an automatic watch shows, moreover, how quickly time may pass on occasions even for an experienced Roentgenologist when engaged in X-ray examinations. A time check is hence, in my opinion, absolutely essential. Regular dose measurement, properly so called, can, however, generally be dispensed with, since the conditions of radiation in screening examinations vary but little; instead of this, the dose specifications which occur in plenty in the literature on the subject can be taken as a basis. The time equivalent of these doses must be worked out subject to all the necessary precautions. The points to be borne in mind, in this connection, are: distance, filter and maximum allowable dose.

The patient should not be placed at less than a certain normal distance from the Roentgen tube. In the various provisions and proposals, 24-40 cm. is specified; 35 cm. is probably the current distance. By some mechanical means (e.g., by a wooden partition permeable to radiation, a frame covered with sail-cloth, or the like) provision must be made to ensure that the distance is not reduced below normal. By way of a filter for the screening of the softest components of the rays, 0.5 mm. of Al., which should be a fixture, is almost universally used. The German regulations further strongly recommend the use of an aluminium supplementary filter of not less than 1 mm. thickness in screen examinations with higher voltages, such as stomach and intestine examinations.

Finally, the determination of a maximum dose is a highly important point. It must be remembered that not only must injuries be avoided in screening examinations, but that, so far as possible, no cosmetic ill-effects must be caused. Consequently, the basic dose must not be the full skin unit dose, but merely a fraction thereof. If the skin unit dose is expressed in terms of *r* units, it must further be considered that the number of *r* units which is equivalent to a skin unit dose in medico-diagnostic radiation is, to say the least, uncertain as yet (see above). Consequently, in order to exclude every possibility of injury, about 100 *r* may be taken as the maximum dose. Under ordinary conditions this entails very short exposures.

On this subject, a great deal has been published. The German regulations recommend the use of the measurements taken by Saupe [2] and by Braun, Hase and Küstner [3]. The latter give, for instance, for a lung examination with 70 kv., 4 ma., 0.5 mm. Al. and 35 cm. target-skin distance, about 7 minutes, for a stomach examination, with a front diaphragm using 100 kv., 6 ma., 0.5 mm. Al. and 35 cm. target-skin distance, about 3 minutes, a time of exposure which is no doubt frequently exceeded in practice. In the latter case, the use of a thicker filter is strongly to be recommended

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[1] E. H. Müller, *Fortschritte Röntgenstr.*, 42, 657, 1930.
[2] *Fortschritte Röntgenstr.*, 37, 536, 1928.
[3] *Ibid.*, 38, 385, 1928.

as already mentioned, since only a very small proportion of the softest components reach the fluorescent screen through the body. When a 2 mm. Al. filter is used, the permissible exposure may be increased to about 5 minutes. Such specifications regarding length of exposure can, of course, only possess a limited validity, seeing that the efficiency of ray output may vary considerably with different tubes and, in particular, that present practice in regard to the measurement of voltage still leaves much to be desired. A recommendation that can be more unhesitatingly and decisively made is that every single set of apparatus should be tested for dosage under the exact conditions of operation.

It is very important that the roentgenologist should not begin the examination until his eyes have thoroughly adjusted themselves to the darkness, and, further, that he should procure exact information as to whether, for any reason, such as previous X-ray examinations, sunburn, disease or the like, increased radio-sensitivity has to be allowed for.

The international regulations sum up all these various points in the statement that screening examinations should be conducted as rapidly as possible with minimum intensities and apertures. In my opinion these general directions require to be considerably supplemented.

In diagnostic X-ray photography of the human body, the conditions are generally more favourable than in screening examinations. The intensities used are commonly very high, it is true, but we have only to reckon with very short exposures, so that the total amount of radiation is small. Thus, for instance, very many lung photographs can be taken without risk to the patient; circumstances arise, however, in which the roentgenologist must carefully reflect whether he may take a further photograph; and this mostly occurs in those very cases of difficult photography which do not always yield a satisfactory result on the first attempt.

In gynæcological diagnosis, consideration must be given to the high radio-sensitivity of the ovaries; by way of upper limit of the dose delivered at the ovaries, I take 5 per cent of the skin unit dose [1].

The skin load is particularly great where use is made of Raster diaphragms (Bucky), which are designed to reduce the scattered radiation between the patient and the plate; in such a case, where lateral photographs of the lumbar region of the spine are taken, only two exposures are permissible.

To sum up, it may be said that greater care in the protection of the patient is required in the medico-diagnostic use of roentgen rays, and that a proper understanding of the dangers involved is indispensable for their avoidance.

7. *Protective Measures in the Use of Gamma Rays, Corpuscular Radiation and Ultra-Violet Light.*

When gamma rays are used, care must be taken, in the very first place, to ensure that only gamma rays are actually being administered — that is to say, that the filtering of the preparation is sufficiently powerful to provide practically complete absorption of the beta rays. This can only be effected with filters of 0.5 to 1 mm. thickness of the metals with very high atomic numbers, the most frequently used being platinum, gold or even silver. The thickness of the filter has much less influence on the intensity of radiation with gamma rays than with X-rays, since the above-mentioned metals only absorb about 1 per cent of the former per 0.1 mm. thickness of filter.

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[1] *Fortschritte Röntgenstr.*, Volume 35, Congress edition, page 54, 1927.

The rays absorbed by the filters themselves excite secondary fluorescent (Roentgen) radiation, which is considerably softer than the gamma rays. In order to cut this off, an outer supplementary filter of about 2 mm. of brass is commonly used. In order, finally, to render harmless the fluorescent radiation engendered in the brass, the radiation may be further made to pass through a layer of rubber. The thickness of the rubber casing provides, at the same time, a means whereby the source of radiation can be set at a specified distance from the surface of the tissue to be radiated.

From what has been said above, it will have been seen that this distance is an essential factor in determining the surface dose, since gamma rays are only absorbed to a very small extent in the tissue and since distance is the main factor of attenuation in the close radiation with small preparations which is most frequently used. In view, however, of the short distances involved, the spatial extension of the source of radiation also plays a part, so that the law of inverse squares does not operate in this case, the reduction depending on the shape and extension of the preparation. This is especially true when a number of small sources of radiation are brought together in applicators.

Dose measurement in the strict sense of the term is not usually carried out in treatment with radio-active preparations; it may, moreover, be dispensed with once the intensity of radiation has been sufficiently accurately determined from the Radium element contents of the preparation, especially as the thickness of the filter is only of secondary importance. It applies, therefore, more especially to normal radium salt preparations. The unit of measurement commonly employed is the milligramme-element-hour or the number of transformed millicuries. As already mentioned, the maximum dose is usually set at 500 mg.-element-hours, with a well-filtered preparation at a distance of 1 cm. from the skin. The strength of the preparation also affects the necessary and permissible time of radiation, and this must be allowed for by means of a suitable time factor.

When very strong preparations are used, as in certain institutes, special measures must be taken to confine the radiation to the body area to be treated.

Beta rays are hardly ever used in medicine except in combination with gamma rays. The containers, in this case, are mostly thin metal and glass capillary tubes, which are loaded with radio-active salt or emanation and implanted into the tumour. Since, at equal energy values, the biological effect of beta rays may be estimated at 100 times that of gamma rays, whereas the depth of penetration is but very small, dosage becomes extremely difficult and is, even now, in a wholly empirical stage. These difficulties are further complicated by the comparatively rapid breaking down of the emanation.

Cathode rays, which are similar in nature to beta rays, and are nowadays produced in considerable quantities are, so far, not being administered to human beings. Here again there arise difficulties of dosage, since account must be taken of the simultaneously engendered Roentgen rays.

Alpha rays, which act about 100 times as powerfully as beta rays, but are absorbed in extremely thin layers, are not used for radiation purposes.

A very widespread form of irradiation is that of ultra-violet light, which is administered principally by quartz mercury lamps (artificial sunlight) and electric arc lamps with carbon, wolfram and other electrodes. The English regulations contain a certain number of provisions on this point. Special protection from radiation is required only for the eyes; they must be protected by goggles which do not allow shorter wave radiation than 3,800 Å.U. to pass through ; this must be spectroscopically tested. The dangers of wrong dosing are not as great as in the case of Roentgen and gamma rays; mercury lamps should, however, also be tested for ray output. Up to the present, no practical unit has been devised for this purpose. A point to be specially remembered is that the ray output drops at first after the lamp is switched on, that it subsequently increases again and only reaches a constant value after 10-15 minutes. The radiation of patients should only begin after this time has elapsed.

To sum up, it may be said that the administration to human beings of other kinds of radiation as well as of X-rays requires special measures of protection for the patient, measures which relate mainly to dosage. Here again, apart from experience, an acquaintance with the principles of radiology is essential in order to avoid injury and to achieve the therapeutic object in view.

C. TABULAR SURVEY OF THE REGULATIONS ISSUED UP TO THE PRESENT IN VARIOUS COUNTRIES.

1. Medical X-ray diagnosis :

   (*a*) Protection of the doctor ;
   (*b*) Protection of the establishment staff ;
   (*c*) Protection of the patient.

2. Medical X-ray therapy. — Protection of the Establishment Staff.

1. Medical X-Ray Diagnosis — (*a*) Protection of Doctor.

	Tube holder	Tube diaphragm	Fluorescent screen	Protection from scattered radiation	Gloves	Apron	Goggles	Observations
International Provisions	Up to 75 kv. 1 mm Pb ,, 100 kv. 1.5 mm Pb ,, 125 kv. 2 mm Pb	—	Protective "surround" of the same protective value as the tube holder	By adequate arrangements	0.5 mm.	0.5 mm.	—	—
Austria	At least 2 mm. Pb	—	2 mm. Pb	—	To be tested for lead equivalence		—	—
Czechoslovakia	At least 1.8 mm. Pb	At least 2 mm. Pb	At least 1.8 mm. Pb	Protective curtain of 1.8 mm. Pb; if not protective "pew" (Schutzkanzel)	0.3 mm.	0.5 mm.	0.5 mm.	Adjacent rooms at least 2 mm. Pb.
Denmark	2 mm. Pb	2 mm. Pb	At least 1.8 mm. Pb	At least 1 mm. Pb laterally and 2/3 mm. Pb	At least 0.5 mm. Pb	At least 2/3 mm. Pb	—	With voltages up to 75 kv. the standards of the regulations may be lowered.
England	See International Provisions.							
Germany	Up to 75 kv. 1 mm Pb ,, 125 kv. 1.5 mm Pb	Same as protection of tube	Up to 75 kv. at least 1 mm. Pb Up to 125 kv. at least 2 mm. Pb	At least 1 mm. Pb	At least 0.5 mm. Pb for palpat. 0.3 mm.	0.5 mm. Pb	—	Diaphragm filtering to catch all primary radiation.
Greece	At least 1.5 mm Pb	—	3 mm. lead glass	At least 2 mm. Pb	0.5 mm. Pb	2 mm. lead rubber	Glass	—
Hungary	3 mm.	—	1.8 mm.	Lead rubber projections of 1.8 mm.	0.5 mm.	1 mm.	—	—
Russia	4 mm. Pb	—	1 mm. Pb 30 × 40 cm.	Projective "pew" with 3 mm. Pb	Compulsory lead equivalence not stated		Or headmask	—
Sweden.	1.5 mm. Pb	2 mm. Pb	At least 1.5 mm.	At least 2 mm. Pb wall	At least 0.5 mm. Pb	At least 1 mm. Pb	—	—
Switzerland . .	2 mm. Pb	3 mm.	2 mm.	Lead rubber plates; if not protective "pew"	0.5 mm.	0.5 mm.	—	Inside lining of gloves for protect. from secondary rays recommended
Madrid	5-6 mm. Pb	—	—	—	—	—	—	—
Proposals. . . .	Protective value to be determined according to voltage, tube current, and distance	Same as tube protection	Protective value same as for tube holder	Cover of patient with 1 mm. lead equivalent	0.5 mm. Pb equivalent	1 mm. Pb equivalent	—	—

1. Medical X-Ray Diagnosis — (*b*) Protection of the Establishment Staff.

	Operator's position	Cabin	Lead Glass window	Valve tube	Adjacent rooms, walls, floor, ceiling
International Provisions	Protective wall of at least 1 mm. Pb Even slight fluorescence of the screen must not be discernible	—	Same value as the wall	—	Protection according to circumstances, if the protection of the tube falls short of the values given in the provisions.
Austria . . . . . (Schönfeld)	Skin erythema dose only to be reached in 10,000 hours	Skin erythema dose only to be reached in 10,000 hours	—	Provisions concerning protection from radiation to be applied, *mutatis mutandis*	Skin erythema dose only to be reached in 10,000 hours.
Czechoslovakia	Protective wall at least 1.5 mm. Pb.	—	—	At least 0.1 mm. Pb	2 mm. if necessary.
Denmark . . .	Protective wall at least 2 mm. Pb 2 × 2 m. as far as possible from the tube	—	—	—	Total protective value 2 mm. Pb.
England	See International Provisions.				
Germany. . . .	Protective wall at least 1 mm. Pb. Distance at least 1.5 m. as close as possible to wall of room	—	—	Indications concerning heating of filament to be complied with	*Photographs :* Primary radiation to be stopped by 2 mm. Pb *Screening examinations :* 0.5 mm. Pb
Greece	Protective wall : 2 mm. Pb in the form of a cabin	*Photographs :* at least 2 mm.	2 mm. Pb	—	At least 1.5 mm. Pb if walls do not consist of masonry at least 10 cm. thick.
Hungary. . . .	Protective wall : 2 mm. Pb 2 × 2 m.	Lead cabin (Ratkoczi) if occasion arises	—	—	No protection necessary.
Russia	Protective wall : of at least 4 mm. Pb. 2 × 1.5 mm.	3 mm. Pb if therapeutic work is simultaneously carried on	20 mm. lead glass	—	—
Sweden	Protective cabin : 2 mm. Pb	At least 2 mm. Pb	2 mm. Pb	—	Total protection at least 1.5 mm. Pb
Switzerland . .	Protective wall : 2 mm.	—	—	—	—
Madrid.	—	—	—	—	—
Proposals . . .	*If protection of tube is :* (1) Adequate : 1 mm. lead wall in front of control-table ; (2) Inadequate : separate rooms	—	Lead value same as that of wall	Must not emit X-rays, otherwise must be protected like X-Ray tube	Protective value to be determined according to : Voltage, tube current, distance and period during which operated.

1. Medical X-Ray Diagnosis — (*c*) Protection of the Patient.

	Filter	Focal distance from the patient	Partition	Dosage	Permissible number of Photographs	Permissible number of Screening examinations
International Provisions	Safety device	—	—	Screening examinations to be conducted as rapidly as possible with minimum intensities and apertures.		
Austria (Schönfeld)	Photographs : 0.5 mm. Al. Screening examinations : 1 mm. Al.	Not less than 24 cm.	—	Not more than 1 skin unit dose of photographic, radioscopic or therapeutic radiation in six weeks.		
Czechoslovakia	1 mm. Al.	—	—	—	—	—
Denmark	Not less than 0.5 mm. Al.	—	—	Same as International Provisions		
England	See International Provisions					
Germany	0.5 mm. Al. With high voltage : 1 mm. Al.	Not less than 35 cm.	At the fixed focal distance	Same as International Provisions		
Greece	0.5 mm. Al.	—	—	—	—	—
Hungary	0.5 mm. Al.	35 cm.	—	—	—	—
Russia	1 mm. Al.	—	—	—	—	—
Sweden	0.5 mm. Al.	—	—	—	—	—
Switzerland	0.5 mm. Al.	Not less than 40 cm.	Of the thickness of sail-cloth	(Watch for checking purposes.) Screening examinations to be as brief as possible. Records to be kept of screening examinations and photographs including unsatisfactory photographs. Warning against repeated photographs and screening examinations.		
Madrid	0.5 mm. Al.	—	—	—	—	—
Proposals	Built in : 0.5 mm. Al. Supplementary filter up to 2 mm. Al. for photographs	35 cm.	At the fixed focal distance	To be checked by timing	To be determined by measurement.	

2. Medical X-Ray Therapy — Protection of the Establishment Staff.

	Tube holder	Protective measures	
		With inadequately protected tubes	Against scattered radiation with adequately protected tubes
International Provisions	Up to 75 kv. 1 mm. Pb ,, 100 ,, 1.5 ,, ,, ,, 125 ,, 2 ,, ,, ,, 150 ,, 2.5 ,, ,, ,, 175 ,, 3 ,, ,, ,, 200 ,, 4 ,, ,, ,, 225 ,, 5 ,, ,,	Protection te be worked out according to circumstances	Protective wall of not less than 2 mm. Operator best stationed outside the X-ray room
Austria . . . . (Schönfeld)	Up to 150 kv. 3 mm. Pb Above 150 kv. 5 mm. Pb	The skin erythema dose must only be reached in 10,000 hours	
Czechoslovakia	Inadequately protected tube 2 mm. Pb. Completely protected tube : up to 125 kv. 2.5 mm. Pb ,, 165 ,, 3 ,, ,, ,, 220 ,, 4.5 ,, ,, Above 220 ,, 6 ,, ,,	Two rooms or cabin Up to 125 kv. 1 mm. Pb ,, 165 ,, 1.5 ,, ,, ,, 220 ,, 3 ,, ,, Above 220 ,, 4.5 ,, ,,	Underneath protection : up to 125 kv. 2.5 mm. ,, 165 ,, 3 ,, ,, 220 ,, 4.5 ,, Above 220 ,, 6 ,, and protective belt of half thickness
Denmark . . .	Up to 130 kv. 2 mm. Pb	Cabin of 4.5 mm. Pb	Protective wall of 4.5 mm. Pb. Covering of the patient 2 mm. Pb.
England. . . .	See International Provisions		
Germany . . .	Up to 125 kv. 2 mm. Pb ,, 190 ,, 3 ,, ,, ,, 220 ,, 5 ,, ,,	Up to 125 kv. 2 mm. lead equivalent Above 125 kv. separate rooms Wall : up to 125 kv. 2 mm. Pb ,, 190 ,, 3 ,, ,, ,, 220 ,, 4.5 ,, ,,	Covering of patient ; laterally : up to 125 kv. 0.5 mm. Pb ,, 190 ,, 1 ,, ,, ,, 220 ,, 1.5 ,, ,, Underneath patient : up to 125 kv. 2 mm. Pb ,, 190 ,, 3 ,, ,, ,, 220 ,, 5 ,, ,,
Greece	According to tube current ; not less than 2 mm.	—	—
Hungary . . .		Partition 5 mm. Pb.	Wall of 4 mm. Pb 2 mm. Pb. under patient
Russia.	Not less than 4 mm.	—	Separate rooms. Partition : up to 150 kv. 5 mm. above 150 ,, 6 ,,
Sweden	Not less than 2 mm. Pb	—	—
Switzerland. .	Not less than 4 mm.	Separation in space. Protective cabin with direct air supply	
Madrid	5-6 mm. Pb	—	2 mm. Pb under patient
Proposals . . .	Protective value to be determined according to the voltage, tube curregt and distance	Separate rooms. Protective wall to be determined according to the voltage, tube current and distance	2 mm. lead wall in front of control table ; covering of patient with 1-2 mm. lead equivalent ; 3 mm. lead equivalent under patient

Lead glass windows	Distance from the tubes	Valve tubes	Adjacent rooms, floor, ceiling, walls	Observations
Lead value equivalent to that of screen or wall	Operator best stationed outside the X-ray room	–	Thickness of the lead equivalent depends on circumstances	Safeguards in regard to filtering required
—	—	Protective regulations concerning radiation to be applied, *mutatis mutandis*	Protection adequate if skin erythema dose is only reached after 10,000 hours	2 dosimeters prescribed. Asbestos filter, safety measures in regard to filtering.
Same lead equivalent as walls	—	0.2 mm. Pb	Up to 125 kv. 1 mm. ,, 165 ,, 1.5 ,, ,, 220 ,, 3 ,,	Masonry 50 cm. thick and concrete 25 cm. thick requires no special protection.
Protective value of the wall	—	—	Total protective value 4.5 mm. Pb	Safety measures in regard to filtering. Below 165 kv., 2 3 of protective values. Above 220 kv., 1.5 of protective values.
—	With inadequately protected tube : up to 125 kv. 1.5 m. above 190 ,, 2.0 m. With prot. tube : up to 125 kv. 1.5 m. above ,, ,, 2.0 m.	Indications governing heating of filament to be complied with	With inadequately protected tube : up to 125 kv. 2 mm. ,, 190 ,, 3 ,, ,, 220 ,, 4.5 ,,	Safety measures in regard to filtering recommended.
Same values as the walls	—	—	Not less than 3 mm. Pb	Dosimeter prescribed.
—	—	—	With an open tube holder 3 mm. Pb	—
20 mm. lead glass	—	—	Not less than 4 mm. Pb	—
Same lead equivalent as walls	—	—	At least 3 mm. Pb	Safety measures in regard to filtering. Dosimeter prescribed.
—	—	—	—	Dosimeter prescribed.
—	—	—	—	2 mm. Pb under the table or on floor.
Protective value equal to that of the wall	To be determined according to the voltage, tube current and protective value	Must not give off X-rays, otherwise must be protected like X-ray tubes	To be determined according to voltage, tube current and distance	Safety measures in regard to filtering. Calibrated dosimeter.

Chapter II.

PROTECTIVE MEASURES AGAINST ELECTRICAL ACCIDENTS IN X-RAY AND SIMILAR ESTABLISHMENTS.

1. *The Dangers of Current and Voltage.*

Apart from short-wave rays, the electric current is an important source of danger in X-ray and similar establishments. Extensive measures of protection have therefore been introduced to provide against this danger. The aspect of the matter usually considered, in this connection, is that of protection against high voltages, but it would be more correct to take the electric current as a basis since, apart from electric shocks, the intensity of the current in the human body determines the extent of the danger involved ; high frequency currents are an exception.

The statements contained in the literature on the subject as to the amount of electric current which must be regarded as dangerous are widely divergent. According to Boruttau, [1] intensities of 20 ma. must be regarded as dangerous, and intensities of 100 ma. must be regarded as involving deadly danger ; nevertheless, much higher intensities are not necessarily fatal, as we know from reports on execution by electrocution.

The voltage which is necessary to produce such intensities of current in the human body depends upon the resistance of the body, and this is liable to extraordinary variations according to external conditions.

If the person concerned is wearing leather footgear and has dry hands, the resistance (according to Perussia) goes up to 50,000 ohms ; with damp hands and feet it drops very considerably. If the extremities are immersed in water, according to Nixdorf and Brandenburg [2], the resistance to direct current is 1,000 to 3,000 ohms, whereas with alternating current it is 200 to 300 ohms. It follows from this, that in certain circumstances, dangerous intensities may be produced in the body even with very low voltages, such as are carried by electric light wires, for example. Cases have been known, for instance, in which persons have been killed through touching a defective light switch whilst in their bath. Even tensions as low as 40 volts can, according to Pietrusky, [3] be fatal.

The behaviour of the tension in time also has an important bearing on the danger involved. Alternating current is far more dangerous than continuous direct current of the same voltage, more especially in the currently employed range of frequencies, for very high frequency currents, as is known, are not dangerous.

2. *The Dangers of X-Ray Apparatus.*

If Roentgen apparatus is considered in the light of the above, it will be found that the voltage operating in the Roentgen tube is always sufficiently high to produce deadly

[1] Quoted by Behnken, *Hdb. d. Physik*, published by Geiger and Scheel, Volume 17, page 197, Berlin, 1926.

[2] Quoted by Behnken. *Op. cit.*

[3] *Med. Klinik*, page 339, 1930.

intensities of current in the human organism, for the voltages normally applied range from 8,000 to 250,000 volts. It must be borne in mind, however, that such intensities of current can only occur if the capacity of the apparatus is sufficient for the purpose. With many sets of Roentgen apparatus this is not the case, so that the danger of such apparatus depends directly on its capacity. On the same grounds, the high-power transformer apparatus of the kind now frequently used in medicine for X-ray diagnostic purposes is deadly dangerous, since it is capable of giving off currents of more than 100 ma. With therapeutic apparatus, on the contrary, the danger is much smaller, since they are usually not capable of any very great output. The dangers of therapeutic apparatus vary, however, according to design. The most harmless is the induction apparatus, since, when there is an appreciable outflow of current, the tension completely collapses. The transformer therapeutic apparatus with and without rectifiers, on the other hand, is far more dangerous, whereas the so-called constant potential sets with condensers approximate more to the induction coil sets.

A certain measure of automatic protection is afforded by apparatus working at high voltages owing to the fact that, on being approached, those parts which conduct the high tension make their presence felt through electric influence, since they cause hair to stand on end and clothes to lie flat against the skin, and since, finally, a spark will jump, which usually has no ill-effects. With apparatus operating at medium tensions from 8 to 80 kv., on the other hand, no such warning is given before actual contact occurs, since the sparking distance and the range of influence action are only small in this case. Hence it is that most of the accidents recorded occur with diagnostic apparatus.

A further point which has an important bearing on danger is the earthing of the apparatus. Technically speaking, such earthing is desirable at a point of the wiring where the voltage is normally nil, since displacements of potential are thereby averted ; from a protective standpoint, however, such earthing is wholly to be condemned. Indeed, if a conductor is touched in apparatus whose high tension circuit is well insulated from the earth in all parts, only a very brief discharge, which may be accompanied by a spark, will pass through the body, and this usually does no harm. If, however, the high tension circuit is earthed at one point, and contact is established at an unfavourable spot, the transformer is short-circuited through the body and the earth, so that a current corresponding to the capacity of the apparatus flows through the body. With the modern constant potential apparatus — which is specially feared owing to the occasional loudly detonating condenser discharges — the danger to life is, in my opinion, smaller than with simple transformer apparatus. This can be explained by the fact that, when there is a considerable outflow of current, here again the tension completely collapses ; thus with a " stabilivolt " apparatus with an earthed mid-point — that is to say, under specially unfavourable conditions — unipolar measurements towards the earth did not yield intensities beyond 10 ma. Animal experiments seem to confirm this, but it stands to reason that protective measures must also be taken with this apparatus, seeing that the shock effect of the jumping spark may in itself be dangerous.

The kind of floor covering also has a considerable influence on the intensity of current occurring when contact is established. Such materials as wood, cork, linoleum and rubber may be favourably considered, whereas stone, tiling or metal floor covering must be avoided. A wooden or similar floor certainly provides protection only against medium voltages but is particularly valuable for our purposes, owing to the highly dangerous character of that type of apparatus. The same applies to wall covering. Earthed metal pipes (water, gas, or heating) can also increase the danger and must be kept out of reach of the high tension.

3. *Protective Measures for the Primary Circuit.*

From what has been said, it will be seen that all X-ray apparatus may be more or less dangerous. Suitable protective measures must therefore be taken to ensure that current engineering standards for high-power equipment are applied so far as the primary circuit is concerned ; it must be borne in mind, in this connection, that, in induction coil sets, for example, the insulation must be tested for self-induction voltage which is considerably higher than the voltage of the mains. With the older type of apparatus, it still happens that regulating resistances and the like on the control table are entirely exposed and unprotected, whilst the protective metal casing of the control table is usually earthed. This may lead to very unpleasant electric shocks if the casing of the control table and the naked wire are simultaneously touched. Such installations are of course inadequate and unwarrantable.

4. *Protective Measures for the Secondary Circuit.*

The protective regulations for the secondary circuit must, on the other hand, be worked out *ad hoc*, since current engineering standards for high-powered apparatus are based upon quite different considerations. It would, for instance, be wholly contrary to those standards to place the Roentgen tube — which carries a high voltage — in immediate proximity (23 cm.) to a human being.

Whilst the international provisions only lay down a few general principles, more detailed regulations have been worked out in a number of countries, the most comprehensive being probably those issued by the German Röntgengesellschaft. Similar instructions have been given in the regulations of the Vienna Elektrotechnische Verein, which were drawn up in direct consultation with the standards department of the German Röntgengesellschaft.

The most essential requirement is that parts conducting high voltage should not be freely accessible. It is best for all these parts to be surrounded on all sides with earthed metallic casings, but this cannot be achieved in all cases. There are only small movable or portable apparatus for medical-diagnostic apparatus that satisfy these requirements, which means that the transformer, the Roentgen tube and the leads are completely surrounded with an earthed metal covering.

In the larger plants, the Roentgen apparatus is placed in a separate room and the high voltage is led off from this into the treatment room either through the wall or through the ceiling. The apparatus room should not be immediately accessible. Some of the regulations recommend, in this connection, a device whereby the voltage in the high voltage generator is deadened when the door is opened. I do not consider this practicable, since it may interfere with the operation of the apparatus and since the said apparatus should be accessible for supervision, even whilst operating. In order to permit of this, the regulations of the Vienna Elektrotechnische Verein require that an enclosed inspection passage at least 1.5 metre in breadth should be provided. In my opinion this is going too far. It should be sufficient for the room to be kept closed and warning notices to be affixed to the door. The main purpose of the above-mentioned arrangement is to protect any person who may be engaged in repairing the apparatus from the risk of the high voltage being switched on unawares from the treatment room. An experienced fitter will, however, always safeguard himself by suitable measures (e.g., by taking out the safety fuses) against the switching on of the voltage from the control table.

From the apparatus room the high voltage conductors may then be taken into a metallic earthed casing which contains the X-ray tube and projects into the treatment room. This tube casing may be mounted in a laterally and vertically mobile cradle in the partition, such, for instance, as the S.R.V. gear of Messrs. Siemens-Reiniger-Veifa. Such equipment is, however, very expensive and somewhat clumsy.

Quite recently considerable improvements have been made in this connection, the Dutch firm of Philips having succeeded, by the use of compressed air, in producing a very small metallic earthed casing for Metalix tubes up to 200 kv., for the high voltage is, in this case, passed through wall ducts from the apparatus room to the treatment room, and the connecting leads are encased in earthed metal covers. In both cases complete protection from the high voltage is afforded in the treatment room, and, in the second, the Roentgen tube is also entirely mobile.

Another method also involves leading the high voltage conductors out of the apparatus room through wall or ceiling ducts ; but the high voltage conductors are not themselves encased in earthed metal coverings, the Roentgen tube being mounted in an earthed metal holder (e.g., Gaiffe oil tank) or in a voltage-proof holder of insulating material (e.g., Wintz gear). The mobility of the tube is very great in the latter case, but this method affords less protection from the high voltage than those previously described. The high voltage conductors must, in this case, bc placed so high that they are not within direct reach of the hand.

In this connection, the German and Austrian regulations provide for a minimum height of 2.20 m. from the floor for voltages up to 75 kv., for 2.30 m. up to 130 kv. and for 2.50 m. up to 250 kv., whilst the Czechoslovak regulations lay down $205+2.5 \cdot \sqrt{kv.}$, a formula which yields practically the same height specifications. In my view, these minimum heights are not sufficient, especially for the lower voltages, which are particularly dangerous, as already explained ; a tall person can easily reach up to 2.20 metres with his hand. The Swiss regulations provide that, if the voltage does not exceed 200 kv., the conductors shall be placed at such a height that no part of the body may inadvertently be brought within 40 cm. of them : the conductors may consequently be placed within reach. On this point, the international provisions are to be preferred, since they stipulate for a uniform minimum height of 9 ft. (3 m.). A graded series of heights from 2.50 m. upwards might perhaps be even better.

At the prescnt moment, there are still many X-ray installations in use, in which the apparatus stands in the trcatment room itself and the Roentgen tube is mounted in an open protective container (lead glass bowl), from which the ends of the tube with the high voltage terminals protrude unprotected. In such a case it must be laid down that the apparatus should be surrounded with insulating material (wooden case) or with an earthed close-mesh metal grating, and that the high tension conductors, so far as they are fixed, should be laid at an adequate height. Open tube holders (except in induction coil sets, which are far less dangerous than transformer sets) should no longer be tolerated for therapeutic uses, since both high voltage poles can be simultaneously touched even by the patient. This is especially so when the tube is set at right angles to the longitudinal axis of the patient's body, as is requircd by the German regulations concerning protection from radiation, in order to avoid the direct radiation which emerges, with such a mounting, along thc axis of the tube extensions.

With the modern ray-proof tubes which need no special protective container, this danger reappears, since both ends of the tube are simultaneously within reach of the patient's hands. The mounting of protective screens must therefore be prescribed, consisting either of earthed metal or, more simply, of Pertinax which is proof against perforation by discharge.

If the high voltage protection consists, not of earthed metal but of insulating material (Pertinax, rubber, wood), the latter must be able to withstand the so-called " sphere test " — that is to say, it must not be liable to be perforated by electric discharge when a sphere of 1 cm. diameter connected with the earth is placed against it for a full minute.

When open tube holders are used, transformer sets with earthing at one point of the secondary circuit are particularly dangerous, as already explained. The German regulations only permit the employment of such apparatus " if a device is fitted which switches off the high voltage in a sufficiently short time when parts conducting high voltage current are touched ". A footnote to this passage adds : " Whether the cut-outs hitherto in use are able to switch off the current in a sufficiently short time has still to be determined by physiological tests ". In my opinion, reliance should not be placed on such apparatus, but everything should rather be done to minimise the risk of contact. The only fitting which has given good technical results in this connection is the automatic overload circuit breaker, which is prescribed by most regulations, but does not afford absolute protection against accidents.

The earthing of the patient, which was formerly a common practice, is to be condemned, owing to the increased risk involved. At this point, it should be observed that, even where measuring apparatus is introduced into body cavities for dosage purposes, the patient is exposed to danger if the instrument is earthed ; it is hence preferable to dispense with earthing in such a case, it being superfluous with a properly designed ionisation instrument. For the same reason, treatment tables for Roentgen therapy should be built of non-conducting material (wood), or should, at all events, be mounted on insulating legs. The connecting leads between the tube poles and the fixed high voltage conductors should, when not in use, be wound up on automatic cable drums fixed to the high voltage conductors, being drawn up sufficiently high to be out of direct reach from the floor. According to certain regulations the feed cable of a Roentgen tube should be connected up with a snap catch ; this would, doubtless, prevent any unintentional disconnection, but such loose contacts should, in my view, be avoided in the high tension circuit, since they might lead to disturbances through high frequency phenomena ; fixed clamp or screw terminals are decidedly preferable.

All high voltage conductors should be sufficiently stout (tubing) to prevent brush discharge ; this applies also to the movable leads, which should therefore consist, for preference, of flexible metallic tubing. For the same reason edges should be avoided and corners should be rounded off with metal spheres.

As regards the laying of the conductors, it is usually stipulated that these should be kept at a distance equivalent to 1.1 mm. per kv. from adjacent metal parts ; but the Czechoslovak regulations go further and provide for a distance of at least 1.2 mm. per kv., whilst the Austrian regulations require 1.3 mm. per kv. for voltages over 130 kv. The minimum distance from the patient must be 1.5 mm. per kv., which, with a voltage of 200 kv., would entail a focal distance of 30 cm., since the Roentgen tube itself must equally be regarded as a high tension conductor. I would recommend that these provisions be made somewhat less rigorous, seeing that the target-skin distance of 23 cm. which was mostly used in the past never to my knowledge caused any trouble, even with a voltage of 200 kv. With most of the modern protective mountings, the distance of 23 cm. can, it is true, no longer be used ; with the latest slender ray-proof tubes, on the contrary, it can.

Special attention must be given to the design of the pedal controls such as are frequently used in diagnostic establishments. Special safeguards against inadvertent switching-on must be provided in this case.

Other safety devices are sound, and light signals which operate whilst the high voltage is in use, and, further, warning notices and the like.

All signalling apparatus, safety appliances, cable drums, earthing wires, etc., should be subject to frequent inspection. It would be desirable to provide that such supervision be carried out at regular intervals by specially empowered authorities.

Since, however, even in the best-equipped establishments, accidents may be caused at times by an unfortunate conjunction of circumstances, it is important that the whole of the employed staff should be trained in first aid for electrical accidents ; instructions on the subject should also be posted up in the working rooms. Similarly, all employees should be acquainted with the instructions for the operation of apparatus.

Chapter III.

HYGIENIC MEASURES IN RADIATION ESTABLISHMENTS.

A. For Persons employed in X-Ray and Similar Establishments.

Apart from the injuries, burns and the like, which can only be caused by extreme incautiousness in the handling of Roentgen rays, etc., and which ought not to occur nowadays, there is a danger that persons constantly working in Roentgen establishments may gradually incur general injuries, consisting mainly of blood changes.

It is hence necessary, in the first place, to make the general external conditions as favourable as possible, in order to increase the powers of resistance of the body, and, secondly, to keep a constant check on the state of health of the staff by regular blood examinations.

1. *The Treatment Room.*

In the first place, the treatment rooms must be spacious and airy. Basements are to be avoided ; if only for the reason that the greater dampness of the air impairs insulation and thereby the efficiency of the X-ray apparatus ; moreover, when ionisation instruments are used for dosing, errors may occur through spontaneous discharge, if indeed the instruments do not completely fail to act.

For hygienic reasons, the use of small ray-proof cabins for the housing of the operator's controls are not to be recommended. Since the protective layer consists mostly of lead, lead vapours may be given off in such a confined space and may produce symptoms of poisoning. Every lead lining must therefore be proofed with a suitable coat of oil paint or the like, and the cabin must be well ventilated. For these reasons, as well as for those stated above, I consider it preferable for the control appliances to be placed in the radiation theatre itself ; adequate protection against radiation can always be secured by keeping them at a proper distance from the Roentgen tube and screening them with a simple protective lead wall.

There are yet other reasons why only spacious and airy rooms should be used. Owing to the effects of the high voltage, the air may be decomposed in such a way that nitrous fumes and ozone are produced which are not conducive to health and produce, moreover, a feeling of weariness. This decomposition of the air is caused more especially by open spark gaps such as occur in particularly large numbers in rotating rectifiers. Such machines must therefore be placed in a separate room or in a well-ventilated wooden housing. Open point-gap measuring instruments also decompose the air and may with advantage be replaced by sphere gaps. Furthermore, silent discharges, corona effects, such as occur at sharp corners and edges of thin conductors, must be avoided. The high voltage conductors must therefore be made of thick metal tubing (2 cm. diameter joined at corners by balls of at least 5 cm. diameter). The thin type of leads to the Roentgen tube which are most frequently used are also dangerous and must be replaced by thick rubber cables or by flexible metal tubing of about 2 cm. diameter. It is best, of course, for the treatment-room to be completely free of high voltage.

In order that deleterious fumes may be removed, good ventilation with a supply of fresh air must be provided. Since the fumes are heavier than air, the most suitable method is to provide for a vacuum exhaust on the level of the floor.

The operation of mercury lamps (artificial sunshine) and open electric arc lamps also seriously vitiates the atmosphere ; here again provision for adequate ventilation should be made.

So far as possible, daylight and sunshine should have free access to treatment rooms. The darkening of the therapeutic radiation theatre is not necessary ; if in distant X-ray treatment, it is desired to ascertain by means of a fluorescent screen whether the cone of radiation covers the whole area of the irradiated field, this can easily be done in full daylight by the previously mentioned device of using a small fluorescent screen which is mounted at the end of a dark tube fitted with an eyepiece.

Both the floor and the walls of the radiation theatre must be smooth and easy to clean. Wood, with linoleum, for instance, is a suitable floor covering, since it is also conducive to protection from high voltage. Similar covering, or a coat of oil paint or the like, is also suitable for the walls ; light tints are most appropriate. For screening-examination rooms dark paint (red or green) is obviously to be preferred, but these rooms should not be kept completely dark.

The doctor and his staff of assistants must be protected from infection by special professional clothing, gloves and the like. In the case of screening examinations it is advisable to provide some protection for the examining doctor against the patient's expectoration, etc.

The international provisions specified 18° C. as a desirable temperature for the rooms ; I believe a somewhat higher temperature, say about 22° C. would be preferable, since the patient undresses in most cases for examination or treatment, and the assistants in the therapeutic installation frequently have to sit motionless for lengthy periods.

2. *Hours of Work for Persons employed in Radiation Establishments.*

The time allowed to the staff for purposes of recuperation must be measured in accordance with the heavy mental and physical strain involved by work in radiation establishments. An eight-hour day, which was taken, above, as a basis for regulations concerning protection from radiation, is probably the absolute maximum that could be contemplated. If work is carried on uninterruptedly for that length of time, the worker's power of concentration must finally be so reduced that the risks to the patient are increased. The international provisions and the regulations of various countries take the view that seven hours at the outside is permissible, whilst Russia even allows but four hours.

According to the international provisions, and according to the Russian regulations, the number of working days in the week should not be more than five, whilst the German regulations provide for 1-2 half-holidays in the week.

As regards annual holidays, the international provisions stipulate for at least one month, Russia two months and the German regulations four weeks.

It is important to make it a rule that persons doing full time in X-ray and similar establishments shall not be called upon for other hospital or similar duty and, in particular, that they shall not have to do night duty.

All employees should be subjected on appointment and at regular intervals thereafter, to careful blood examinations, in order that physical unsuitability may be quickly detected and a change of occupation recommended. I have found that, where the best possible protection is used, a seven- to eight-hour day, from one to two free afternoons per week, and four weeks' annual holiday is a satisfactory system; the blood examination is made at the time of appointment and, thereafter, at intervals of two months, the findings being recorded on each occasion.

3. *Hygienic Measures in Other Radiation Establishments.*

Measures corresponding to the particulars given above should be taken in industrial establishments where X-ray apparatus and tubes are manufactured or used for examinations, etc.

As already mentioned — when protection from radiation was discussed — special arrangements should be made in places where work is carried on with radio-active substances. In the handling of radium salts and in the filling of emanation containers, rubber gloves must be used ; in the latter case, the air in the room must be continually renewed by exhausters. Recently cases have been reported in which female workers engaged in laying on luminous colours containing radium injured themselves by moistening the brush with their lips.

It sometimes happens with mercury lamps (artificial sunshine) that the mercury container bursts and splashes the mercury about ; a fitting should therefore be mounted to catch the mercury, since mercury poisoning may otherwise gradually occur. The same danger also arises with the type of burner in which the electrodes are not fused in and thus made airtight, but are merely cemented in ; here again the heat may cause the mercury to be expelled and to evaporate.

B. Hygienic Measures for the Protection of the Patient.

1. *General Remarks.*

The existing regulations also need to be supplemented in the matter of hygienic measures for the protection of the patient from injury.

The treatment beds for patients must always be covered with clean sheets. In X-ray therapy, special attention must be given to the cleanliness of the radiation " cone " and to the protective covering material. Compressor " cones " which (even in photography) come into direct contact with the skin must be of suitable, easily disinfected material, and be cleaned on each occasion after use. The lead plates which are used as covering round the edge of the field may, with advantage, be provided with linen covers, which should be regularly washed ; lead rubber covers should be constantly disinfected.

The preliminary treatment and after-treatment of patients subjected to therapeutic radiation may also be included among hygienic measures. For instance, the inunction of the radiated areas of skin, which, as experience has shown, may appreciably reduce the risk of injury, is of outstanding importance. In a general way, all patients undergoing X-ray treatment should be provided with a set of rules of conduct, calculated, if observed, to avert late injuries.

In diagnostic establishments as well, all objects with which the patient comes into direct contact should be made of suitable, easily disinfected, material and should be kept spotlessly clean. Such are : the wall in front of the X-ray tube against which the standing patient leans in screening examinations and X-ray photography, the radioscopy, or photography, table, the back of the fluorescent screen, rubber gloves or instruments used for palpation, the lid of the Roentgen cassette, the diaphragms for scattered rays, the compressor " cone ", etc.

As regards X-ray diagnosis, it would also be desirable to have regulations concerning the testing and use of opaque substances which must not be deleterious.

In the use for radio-active substances, too, the utmost cleanliness is required for the protection of the patient. This applies, for instance, to applicators, which come into direct contact with the patient's skin ; but radium preparations themselves, and their filtering containers, which are introduced in certain cases into body cavities, must be sterilisable. It would be best if the preparations could be boiled as they are.

In radiation with open electric arc lamps, white-hot particles may be thrown off and injure the patient. Precautions must be taken against this as well as against injuries caused through the bursting of quartz burners.

2. *Measures for the Avoidance of X-Ray Sickness.*

At this point, a word may be said as to the measures required for the prevention of X-ray sickness, that unwelcome accompanying phenomenon of deep X-ray therapy, which is apparently due to a combination of several factors. The underlying causes may be the effects of the X-rays, or of the high-frequency oscillations produced by the high voltage, or the vitiation of the air by the high voltage.

The effects of the X-rays themselves can, of course, not be eliminated ; they should, however, be confined strictly to the area to be radiated. This is almost completely achieved, with the modern ray-proof tube holders for instance, and with the ray-proof tubes. Since they have been in use, cases of X-ray sickness have become much less frequent than they were when the old open tube cases were employed. It has been thought that the sickness should be ascribed to the more intense general radiation involved in the latter case. Endeavours must therefore be made, for the patient's sake as well, to fit the protective material to the X-ray tube itself.

The effects of the electric high voltage are due, *inter alia*, to the high frequency oscillations which are concurrently produced when the X-ray tube is in operation. It has been found that such electric fields are injurious to small animals, when they are sufficiently strong, and it may be assumed that they can also do damage to the human organism. If the high voltage conductors are properly laid, in accordance with the rules set forth above, or if, indeed, the treatment-room is completely free from high voltage, this factor must disappear.

Finally, the fact that the vitiation of the air through the production of ozone and nitrous fumes may have injurious effects on the weakened organism of the patient is enlightening. By suitable arrangements, such as have been discussed above, this factor, too, may be eliminated.

Experience has confirmed that, when all requisite measures in respect of protection from radiation, protection from high voltage, and ventilation, are taken, X-ray sickness becomes much less frequent and is limited thereafter to exceptional cases.

C. Tabular Survey of the Regulations hitherto published in Various Countries.

HYGIENIC MEASURES IN RADIATION ESTABLISHMENTS

	Hours of work	Holidays	Medical examination and blood-composition test	Other work	Protection from infection	Observations
International provisions	Maximum of 7 hours 5 days	At least one month per annum	—	Night duty prohibited	—	Holidays to be spent so far as possible in the open air
Austria . . . (Schönfeld)	—	—	—	—	Objects coming into direct contact with patient to be capable of easy disinfection	—
Czechoslovakia	—	—	—	—	—	—
Denmark. . .	—	—	—	—	—	—
England . . .	See international provisions					
Germany. . .	Maximum of 7 hours, free Sunday and 2 half-holidays recommended	4 weeks per annum	At least once a year. Findings to be recorded	Prohibited	—	Examination before appointment
Greece. . . .	Maximum of 8 hours, with break of 2 hours	At least 6 weeks. Aft. 5 years at least 2 months	Regularly twice a year. Examination of urine	—	—	Desirable that employees should not work on Sundays and holidays
Hungary . . .	Not more than 6 hours at a stretch	4 weeks in summer, one week in winter	Once a year	—	—	One free day per week
Russia . . .	4 hours	Two three-weekly periods per annum	Every six months	—	—	For female workers, 8 weeks, maternity leave before and after confinement
Sweden . . .	Maximum of 8 hours, with break of 2 hours	Six weeks, in two periods. After 5 years, at least 8 weeks	Twice a year	—	—	Desirable that Sundays and bank holidays should be free
Switzerland. .	—	—	—	—	—	—
Madrid . . .	—	—	—	—	—	—
Proposals . .	7 to 8 hours, daily ; 2 free afternoons per week	One month per annum	On appointment, and every 2 months	Prohibited	Professional clothing	—

Chapter IV.

PROTECTIVE MEASURES AGAINST THE DANGERS OF X-RAY FILM FIRES.

1. *Nitro-cellulose and Acetyl-cellulose Films and Their Properties.*

For the purposes of medical X-ray diagnosis, films are nowadays used almost exclusively as supports for the photo-sensitive layer, such films being of the double-coated type.

So far as the danger involved is concerned, stress must be laid on the great difference between a cinematographic and a Roentgen film.

For the material of the Roentgen film, two substances of different chemical composition are used, the ordinary film, consisting of nitro-cellulose, and the so-called safety film which is made of acetyl-cellulose. The first double-coated Roentgen film was made in Germany by Dr. Max Levy, in Berlin, as far back as 1897. [1]

Numerous tests have latterly been made in authoritative quarters to work out reliable standards by which the dangers attaching to both kinds of film can be gauged. Lehmann [2] (Photo-technical Institute of the " Technische Hochschule ", Berlin) found, for instance, that samples of films in the condition in which they are used, i.e., with a developed layer of emulsion, caught fire at the following temperatures : nitro-cellulose films 175-180°, Agfa safety films 400-405°, Kodak safety films 440-445°, Pathé films 440-445°. The inflammability was tested on horizontally stretched lengths of film 3.5 cm. broad and 20 cm. long. Complete combustion took not more than 15 seconds with nitro-cellulose films ; the Pathé film ceased to burn as soon as the flame was removed ; the Agfa film flared up more fiercely, but only went on burning for a few centimetres. The Kodak film burned more slowly, but usually right to the end and took at least 50 seconds. In the case of double-coated X-ray films, conditions are not more unfavourable.

When nitro films burn rapidly with an adequate supply of oxygen, only harmless gases such as carbon dioxide and nitrogen are given off, whereas, with incomplete combustion, carbon monoxide, nitrous oxides, and small quantities of prussic acid are given off, 1 kg. of celluloid being able to produce about 600 litres of gas. The safety films shows, however, no tendency to smoulder; smouldering only takes place if the air is cut off and the film is sufficiently heated. The process of flameless combustion, such as occurs in nitro films could not be induced in safety films by tests at the " Chemisch-technische Reichsanstalt [3] ". When acetyl-cellulose films are made to smoulder by artificial means, they give off, like nitro films, small quantities of prussic acid. But this can never give rise to any serious danger. Under favourable conditions the nitro film, once it has caught light or has been sufficiently heated, easily passes over into a process of flameless combustion. The resulting gases are inflammable and even

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[1] Wertheimer *Über die Röntgenfilmaufbewehrung*, " Strhlentherapie ", Volume 36, 1930, p. 573.
[2] *Fortschritte Röntgenstr.* 41, 989, 1930.
[3] *Fortschritte Röntgenstr.* 41, 991, 1930.

explosive if mixed with the right quantity of air. The fumes of the nitro film are in part highly toxic (see hereafter).

The great inflammability of the ordinary cinematographic film and the dangerous nature of the fumes given off on slow combustion have long been known. The dangers connected with Roentgen films were pointed out by Wertheimer as far back as 1924 when the double-coated X-ray film was introduced in Germany. For this reason, in Germany, for instance, the Ministry of the Interior, in a memorandum of December 27th, 1928, on the storage of X-ray, etc., celluloid films used in hospitals, issued instructions the observance of which should greatly reduce the dangers attaching to X-ray films.

2. *Accidents caused by the Burning of X-Ray Films.*

In May 1929, there occurred in Cleveland, Ohio, a fire disaster of such magnitude that it appeared urgently necessary to revise the existing regulations and to expedite their enforcement in practice. Now, to be sure, we are threatened with regulations which, in the opinion of experts, overshoot the mark.

Whilst in other cinematographic film fires, which have been fairly numerous, no deaths were reported which could be ascribed with certainty to the inhalation of poisonous gases, in Cleveland 125 fatal casualties occurred, all of which were caused by gas poisoning. The enquiry showed that the disaster only reached such proportions owing to an unfortunate chain of circumstances.

The film store, which contained from 3 to 4 tons of films, was in itself fire-proof ; it was in the basement and had no connection with the outside air ; it was shut off by a fire-proof iron door. In close proximity to the upper film rack, a large steam-heating pipe ran through the room. This was examined for a defect on the day of the disaster, and stripped for that purpose of the insulating lagging. As a result of this, it is presumed that overheating occurred, leading to the internal decomposition, and consequent flaring, of the nearest films. When an attempt was made to extinguish the fire, an explosion occurred which spread the fumes all over the establishment through a ventilation duct and the staircase shaft. Owing to the lack of air, the fire could only smoulder slowly, so that the production of fumes by the internal decomposition of the nitro-cellulose was stimulated,

On the scene of the disaster, many of the victims were found dead sitting at their desks, etc., and the cause of sudden death was taken to be prussic acid poisoning. Chemical experts, however (Knutsson [1]), contested this, saying that 1 kg. of celluloid can only produce 5 litres of prussic acid, and that prussic acid loses its toxicity in the air in a few minutes. It was therefore suggested that other poisonous gases might have contributed ; for instance, that phosgene was formed by burning chloroform fumes which may have been evolved in the *pharmacy*, which was also involved in the fire.

A thorough enquiry into the Cleveland disaster was made by a Commission of the American Chemical Warfare Service, and the findings recorded in an elaborate report [2]. The large number of casualties which occurred even among persons who only came in for a moment is ascribed to the gases given off during the fire — namely, carbon monoxide and nitrous fumes — coupled with the lack of oxygen. The nitrous fumes involved in this case are : NO, NO_2 and N_2O_4. According to the tests performed, the inhalation of the nitrous fumes in a concentration of 0.6-1 mg. per litre of air (0.029-0.049 per cent by volume) is immediately fatal, whilst carbon monoxide, in a concentration of 12.5 mg.

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[1] *Acta radiolog.*, Volume 10, 566, 1929.
[2] *The Disaster at the Cleveland Hospital Clinic*, Government Printing Office, Washington, 1929.

per litre of air (1 per cent by volume) can only be tolerated for 4-6 minutes. (It nevertheless remains a puzzle how the fitter who was repairing the heating can have escaped with his life, as apparently he did, although, in the attempt to extinguish the fire, he came within close range of the conflagration, whilst, a short time afterwards, numerous persons were being instantly killed in remote parts of the building.)

Quite recently a film fire was reported [1], which broke out in the University of California Hospital and involved the destruction of 500 lb. of nitro-cellulose film. In this case only three firemen and a few nurses sustained mild gas poisoning, which took the form of a temporary indisposition. The fire would probably have been confined entirely to the film store had there not been a fanlight one foot high over the door, through which the flames found an exit.

3. *Regulations for the storage of X-ray films.*

As a result of these and other film fires, regulations for the storage of X-ray films have recently been issued, which take into account the results of tests undertaken by the competent authorities in conjunction with the firms concerned.

The following may be mentioned :

1. Regulations for the Storage and Handling of X-ray Films in Medical Establishments, published by the German Roentgengesellschaft [2].

2. Regulations for the Storage and Handling of Photographic and X-Ray Nitrocellulose Films, published by the American Roentgen Ray Society [3].

Both sets of regulations agree in stating that no special precautionary measures are required when so-called safety films of acetyl-cellulose (cellulose acetate) are used. This view has, it is true, not passed unchallenged in the literature on the subject (Herrnkind [4] and C. M. Wood [5]), it having been pointed out that prussic acid is evolved by smouldering acetyl-cellulose. The above-mentioned detailed investigations of the " Chemisch Technische Reichsanstalt ", show, however, that the gases evolved by the incomplete combustion of safety films (prussic acid and sulphuretted hydrogen) can never give rise to any serious danger, since flameless decomposition does not occur with safety films, and smouldering, just like dry distillation, can only be maintained by a constant supply of external heat and by cutting off the air. In such circumstances, even wool, hair, feathers, and so on, give off prussic acid and sulphuretted hydrogen in addition to carbon monoxide. The storage of safety films, therefore, entails no other dangers than that of paper, documents, etc., to which no special regulations apply.

According to the German regulations, a film is to be regarded as an X-ray safety film when a strip 3.5 cm. wide and 20 cm. long, which is held on edge in a horizontal position, and lit from underneath at one end with a match, either does not continue to burn after the removal of the match or requires more than sixty seconds for complete combustion. Safety films must be indelibly marked as such, the mark to be affixed on each single film and on the packing.

The American regulations strongly recommend the general and exclusive use of safety films; it is pointed out, however, from other quarters, first, that safety films are more expensive than ordinary films, secondly, that safety films can only be stored for

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[1] *Acta radiolog.*, Volume 10, 566, 1929.
[2] DIN-Roentg., 3, Beuth. Verlag G.m.b.H., Berlin, page 14.
[3] *American Journal of Roentgenol.*, 23, 81, 1930.
[4] Herrnkind : *Röntgenpraxis*, p. 649, 1929.
[5] C. M. Wood : *The Modern Hospital*, No. 3, page 78, 1929.

a limited period, and, finally, that it is uncertain as yet, whether the finished photographs of safety films may not undergo changes in course of time.

The difference in price of about 20 per cent is in itself sufficient to make the not inconsiderable cost of fire-proof equipment for the storage of ordinary films less great in some cases than the extra outlay entailed by the constant use of safety films. There being, moreover, some uncertainty as to the durability of the latter, regulations exclusively authorising the use of safety films would encounter considerable opposition. The raising of the safety film to the same level as the nitro-cellulose film, in respect both of price and quality, must, however, continue to be our objective.

Owing to the comparative harmlessness of the safety film, the provisions concerning storage relate only to nitro-cellulose films.

The quantity of film to be stored or accumulated has, of course, an important bearing on the nature of the protective measures required. Generally speaking, it is advisable to discard all films the storage of which is not necessary. Such films should, however, not be disposed of by burning, since this, too, will give rise to dangers demanding special precautionary measures; they should rather be sold to buyers of such material.

The number of finished X-ray photographs which may have to be dealt with varies considerably according to the number of patients attending the institutes. In the larger hospitals, 100 photographs per diem should be allowed for — that is to say, given 300 working days, 30,000 films a year. In Germany (a decision not having yet been given by the Reichsgericht) photographs must be kept for a number of years, so that a quantity of 300,000 films would accumulate. As the larger sizes of about 30 × 40 cm. are the most frequently used, this would mean about thirteen tons of film, assuming a weight of 375 gr. per sq. m.

Since the storage of so large a quantity in a single room is highly dangerous, it is advisable to subdivide it. A clear distinction between a so-called reference library *(Präsingbibliothek)* and X-ray film archives was first made by Wertheimer.[1] Since, moreover, there is no need for all X-ray photographs to be immediately available, a provision may be separately made for a small store for current use, a medium-sized store which is easily accessible and a large store for films which have been filed away but might in certain circumstances be required again.

By way of daily supply for the small store, the German regulations provide for not more than 10 kg. net weight (i.e., about 52 dozen 18 × 24 cm. films, or 18 dozen 30 × 40 cm. films) of unexposed films in their original packing. The stored films should be kept at an adequate distance from radiators and fires. Furthermore, the regulations provide for not more than 5 kg. (i.e., 308 films of 18 × 24 cm. or 110 films of 30 × 40 cm.) of developed film, which should be kept at an adequate distance from radiators and fires in boxes of hard wood or other material which does not readily conduct heat or burn.

According to the American regulations, undeveloped films must be kept in metal boxes — which may be lead-lined — on racks two feet above the floor, or in tested double-sided vented cabinets. The negatives should be stored in sets of not more than six, in thick paper covers, or in sets of not more than twenty-five in cardboard boxes.

The idea of subdividing the films by means of paper pockets or cardboard boxes, which finds expression in these regulations, proved satisfactory in the combustion tests that were performed (Effenberger[2]), although it would seem that smouldering and the consequent fuming of the celluloid is facilitated, and burning with open flame

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[1] Wertheimer: *Strahlentherapie*, Volume 36, page 580, 1930.
[2] Effenberger: *Röntgenpraxis*, I, 643, 1929.

reduced. In the tests, such packets of films were only burnt at the edges and the production of fumes was small; it would seem that the application of intense heat for a considerable period of time — such as is not likely to occur in fires — would be necessary to cause such packets to smoulder right through.

The German regulations define as a medium-sized store one in which up to 150 kg. net weight (i.e., about 9,240 films of 18 × 24 cm. or 3,300 films of 30 × 40 cm.) are kept in a single room. This must have fire-proof walls and at least a fire-resistant ceiling as well as fire-resistant doors; the latter must be smoke-proof and self-closing and may only give on to a landing. (Hard-wood doors or ordinary soft-wood doors covered with tinplate on all sides are regarded as fire-resistant ; such doors must of course have no lights.) The room must have a window of thin glass, not less than 0.5 sq. m. in area, giving on to the open ; in addition, a ventilation duct communicating with the open air must also be provided, which is automatically opened by an excess pressure of 6 kg. per sq. m., and must have an area in cross section of at least 0.25 sq. m. No open flames or inflammable materials must be kept in the room. Heating pipes and the like must be provided with a protective covering so shaped that films cannot be laid on them. The films themselves must be placed in a safe which fulfils certain conditions (see below). Where considerable quantities are involved, a separate room must be used for each 150 kg. net weight of film; these rooms must not be intercommunicating.

The American regulations, on the other hand, prescribe the use of cabinets of not more than 30 cubic ft. content, which must be in communication with the open air. When the weight of film to be stored exceeds 200 lb., two separate cabinets must be used. Cabinets with a capacity of more than 100 lb. must be fitted with an automatic sprinkler, unless each compartment contains less than 30 lb. of film and the cabinet is so designed that fire cannot spread from one compartment to the other. The opening communicating with the outside air must have an area in cross section of at least 1 sq. in. per cubic ft. of room. No special stipulations are made as to the fire-proofing of the place in which the cabinets are stored.

The German regulations define as a large store one in which more than 150 kg. net weight of film are kept in a single room. A room of the large store should not contain more than 4,000 kg. net weight of films (i.e., about 246,000 films of 18 × 24 cm. size, or 88,000 films of 30 × 40 cm. size). Where the quantity to be stored is greater, several completely separated rooms must be used. In dwelling-houses, large stores may only be installed in the lofts. The walls and the floor must be fireproof. The room must have a window, giving on to the open, glazed with thin glass, provided with protection against sunshine and having an area equivalent to 5 per cent of the floor area and in no case less than 0.5 sq. m. When the store is installed, special care must be taken to ensure that the fumes given off in the event of a fire could not gain access to the landings or to the staircase shafts; the latter must be fitted at the highest point with a vent, at least 0.5 sq. m. in area, that can be operated from the ground floor. Large stores must have no heating apparatus; if heating pipes are carried through, special conditions must be fulfilled, and this applies also to electric light equipment. If the large store is installed outside in a special small building, this must be so situated that neighbouring inhabited houses will not be involved in any fire. As regards the manner in which the films are to be kept in the large store, no special regulations have been laid down, but the use of the original cardboard packing is recommended.

The American regulations mention special fireproof materials for the construction of storage rooms. The rooms should be provided with self-closing fire protection doors and should have no fan lights. For very 64 sq. ft. of floor area an automatic sprinkler must be provided; this may only be dispensed with if the storage room is installed under the roof and if no danger to the building can arise through fire or fumes. The room must be connected with the open air by an opening having an area in cross section of at least 1 sq. in. per cubic ft. of content; this connection with the open air can also be secured by means of reliable automatic appliances which open the windows in the event of fire. Heating must only be effected by hot water or low pressure steam; radiators and pipes must be suitably protected. Special regulations have also been laid down concerning electric light ; it is specially emphasised that no plug connections for portable lamps must be fitted. The protective measures may be relaxed if the films are kept in separate shipping containers; in this case storage is permitted up to 500 cubic ft. without sprinklers, the corresponding limit without such shipping containers being but 250 cubic ft. When the volume stored without shipping containers exceeds 1,000 cubic ft. the regulations governing storage-rooms apply.

General provisions in the German and American regulations have reference to fire extinction apparatus, the prohibition of smoking, the display of warning notices, etc.

The German regulations further contain provisions specifying the conditions to be fulfilled by the safety cabinets. These must be tested by the " Chemisch-Technische Reichsanstalt " and must satisfy the following requirements. When the room is burning fiercely, the contents of the closed cabinets must not begin to smoulder or burn before the lapse of half an hour. A cabinet must not contain more than 150 kg. net weight of film in the customary protective cover, and must be fitted with compartments each with a capacity of not more than 40 kg. These separate compartments should only pull out one at a time, and the cabinet must be so built that the fire cannot pass from one compartment to the other. No excess pressure must occur inside the cabinet when the contents are in process of flameless decomposition.

4. *Conclusions.*

If these regulations are reviewed, it will be seen that the experience gained in the Cleveland disaster has been largely turned to account. The most essential point is doubtless that rooms in which large quantities of film are stored should be shut off by fire-proof material from the inside of dwelling-houses, that good connection with the open air should be provided and especially that there should be no possibility of the fumes caused by smouldering spreading to the rest of the building.

When the German and the American regulations are compared, the reader is immediately struck by the fact that the latter provide compulsorily for the extensive use of sprinkler apparatus, whereas the former contain no reference to this. Tests have shown, it is true, that, when sprinkler apparatus is used, a fire may in some cases be quickly extinguished, since the cooling down of the films is specially effective as a means to that end ; to this must be added the circumstance that the toxic nitrous fumes are readily soluble in water and can to some extent be rendered harmless by this means. On the other hand, such equipment involves considerable complications, and it is not impossible that the plant, like any automatic appliance, may break down in an emergency. Von Feilitzen [1] has, however, pointed out that sprinkler equipment might conceivably prove a double-edged sword, preventing the free burning of the film and bringing about, instead, an incomplete form of combustion which would be conducive to the production of poisonous gases.

The American regulations only allow large stores to be installed without sprinkler equipment if the premises are in the lofts. Similarly, the German regulations only permit the installation of large stores in dwelling-house immediately under the roof. In

[1] *Brandskydd, Svenska Brandskyddsföreningenstidskrift*, Okt. 1929.

practice, difficulties will, however, frequently be encountered, since the structure of the roof usually consists of wood and the temperature under roofs may rise very high in summer.

Knutsson [1] has given a detailed description of the equipment of a large store of the " Svensk Film Industri ", which was constructed after careful tests, and has a capacity of 28,500 kg.

In order to provide against the destructive effects of explosions of film gas, the German regulations regard to some extent as safety valves openings of at least 0.5 sq. m. glazed with thin glass which is smashed by excess pressure on the inside. The American regulations, on the other hand, require, for large stores, openings of at least 0.5 sq. in. per cubic foot of room; they may be closed by windows which open automatically on the outbreak of fire; here again, it should be borne in mind that every automatic appliance is liable to fail on occasion.

If these regulations for the storage of X-ray films are compared with those previously in force, it is hard to resist the impression that, owing to the dreadful disaster at Cleveland, regulations have been issued which can scarcely be complied with by a large number of X-ray institutes. The German regulations, in particular, go far beyond the requirements that the average institute can satisfy, since the installation of a fireproof room in the cases specified involves special structural alterations. I consider, moreover, that the capacity of the " medium-sized store ", which is set at 3,300 films of 30 × 40 cm. size, is not sufficient even for smaller institutes.

In my opinion the instructions issued on December 28th by the German Ministry of the Interior are fully adequate, providing, as they do, that fireproof safes should be used for storage, and laying down no special requirements in respect of the fireproofing of the storage-room, so far as smaller stores of up to 15,000 films are concerned. The stipulation that the separate compartments in the safe shall be so interlocked that only one compartment can be opened and drawn out at a time is moreover a complication that must greatly increase the price of the safes if the mechanism is to be reliable.

In my opinion much more importance should be attached to proper instruction in the handling of X-ray films, and on this point strict regulations should be issued, for 5 kg. of film, when incautiously handled, are just as capable of causing a dangerous fire as a larger quantity. Suitable rules of conduct should, however, be worked out for cases in which a film fire has actually started — an accident that may be brought about by an unfortunate combination of circumstances, even with the strictest storage regulations. Similarly, all members of the staff should have training in first aid for gas poisoning, a point on which the report of the Chemical Warfare Services, for instance, contains recommendations.

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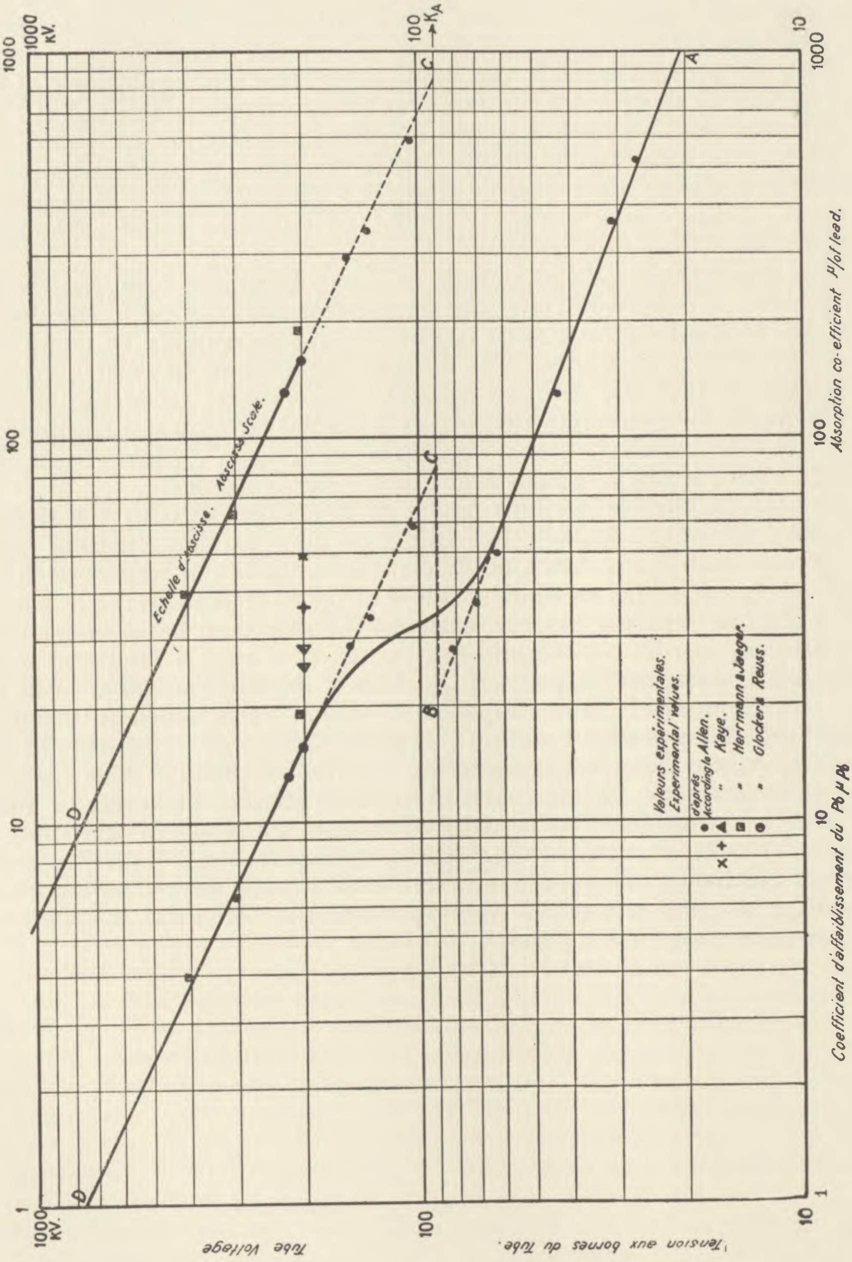
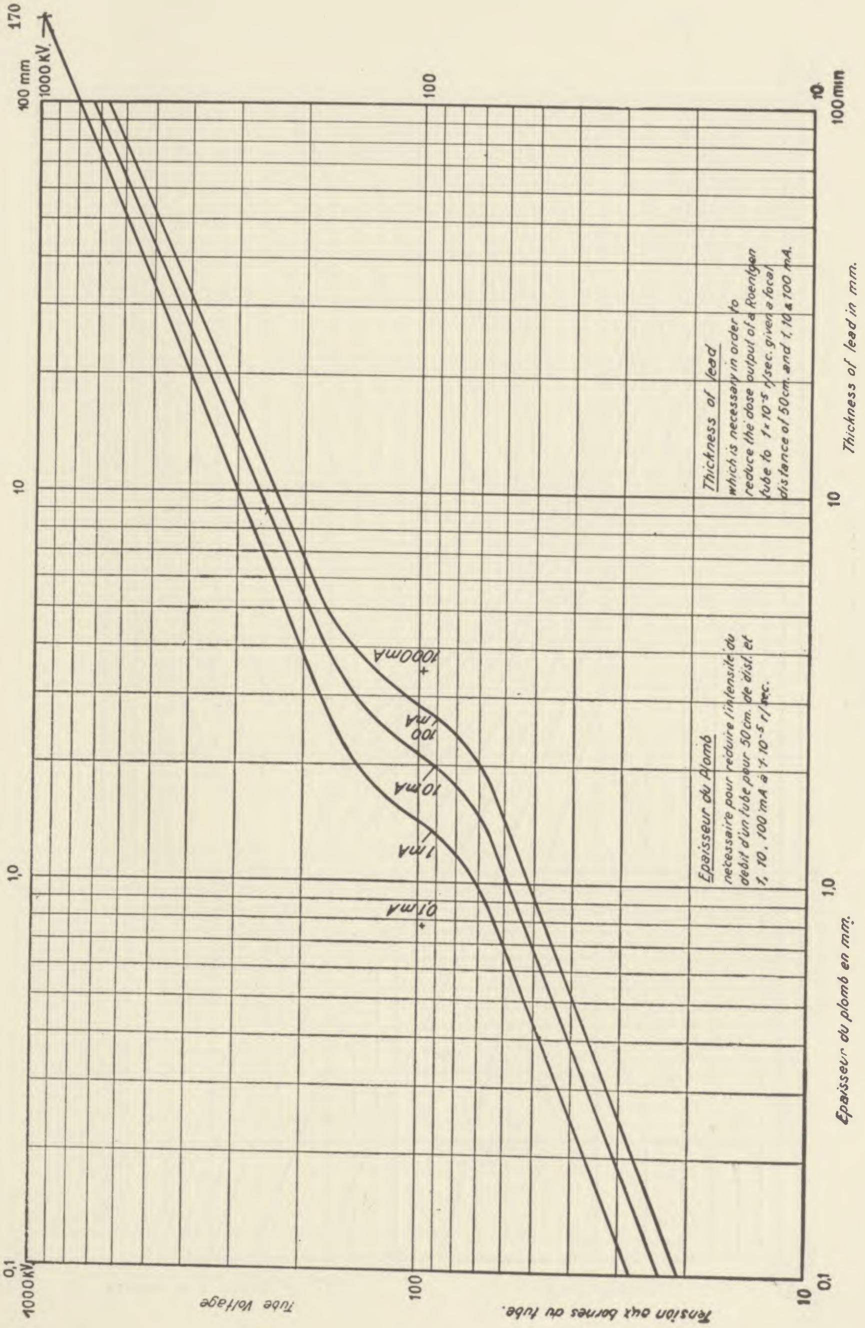
[1] *Acta radiol.* 10, 566, 1929.

Protection from Radiation



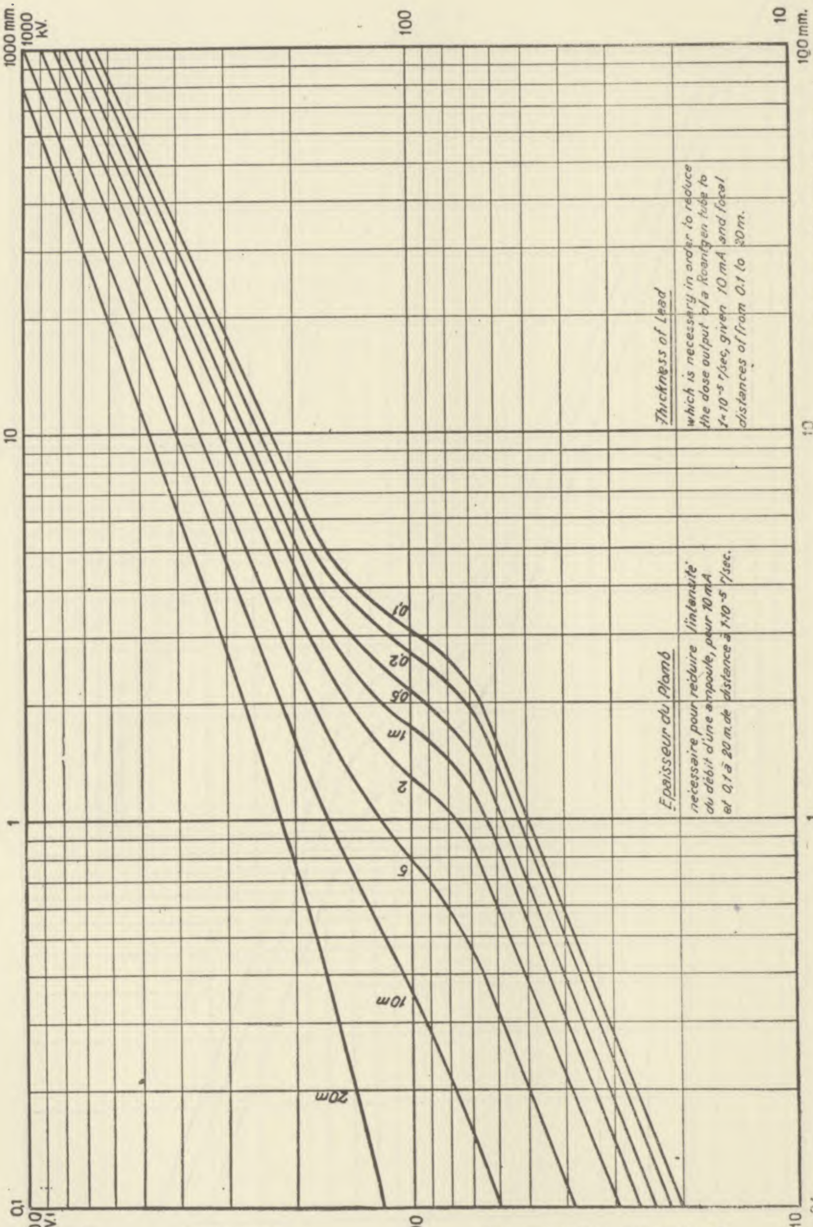
GRAPH. I.

Protection from Radiation



GRAPH. II.

Protection from Radiation

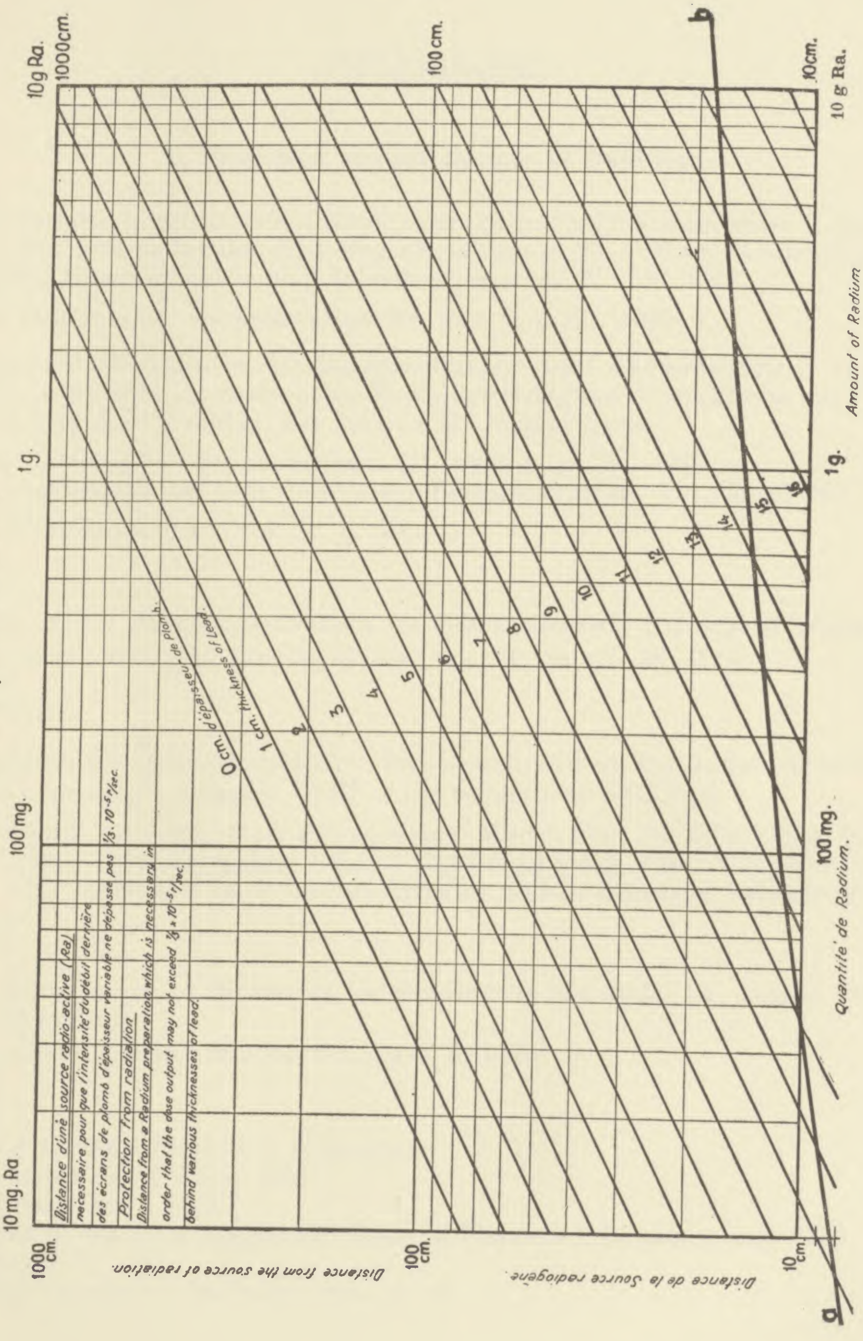


Tube Voltage — Tension aux bornes du tube

Thickness of Lead in mm. — Epaisseur du plomb en mm.

GRAPH. III.

Protection from Radiation



GRAPH. IV.

BIBLIOGRAPHY.

I. Protection against Danger of Radiation.

" Richtlinien der Internationalen Röntgenstrahleneinheits-Kommission ", angenommen von dem Internationalen Radiologenkomitee am 26. Juli und Genehmigt von dem Zweiten Internationalen Radiologenkongress am 27. Juli 1928.

Acta Radiologica, Supplementum III, Pars I, p. 61, 1929.

" Internationale Richtlinien für Röntgenstrahlen- und Radiumschutz ", angenommen von dem Zweiten Internationalen Radiologenkongress in Stockholm am 27. Juli 1928 auf Grund des Vorschlags der Sektion für Radio-Physik.

Acta Radiologica, Supplementum III, Pars I, p. 66, 1929.
Fortschritte auf dem Gebiete der Röntgenstrahlen, Vol. 39, p. 343, 1929.
Strahlentherapie, Vol. 32, p. 606.

Austria.

Schönfeld, A. : " Schutzmassnahmen im Röntgenbetrieb (*De lege ferenda*). "
Wiener medizinische Wochenschrift, Nos. 35, 36, 37, 38, 1929.

Czechoslovakia.

" Vorschriften des Čechoslowakischen Elektrotechnischen Verbandes für elektromedizinische Anlagen ". Chapter XVIII of the regulations ESC 1930 [1].

Genehmigt von den čechoslowakischen Ministerien für öffentliche Gesundheitspflege. Herausgegeben beim " Elektrotechnický svaz čechoslovenský ", Prag XII, Vocelova 3 in čechischer Sprache und in deutscher Uebersetzung.

Denmark.

" Betaenkning fra det af Ministeriet for Sundhedsvaesen under 24. August 1927 nedastte Røntgenudvalg. "
København, Trykt hos J. H. Schultz A/S, 1928.

England.

X-Ray and Radium Protection Committee.
Revised Report No. 1 (Dec. 1923).
Revised Report No. 2 (1925).
Abgedruckt in den Mitteilungen des National Physical Laboratory, Juni 1925.
Radiology, III, p. 171.
The British Journal of Radiology, 282, p. 19.

---

[1] Předpisy elektrotechnického suazu československého 1930. Cást XVIII. Elektrická ařízení Iékařská.

England.

Third Revised Report, May 1927.

British Journal of Radiology, Vol. 32, No. 326, p. 330, 1927. (Enthält Schutzmassnahmen gegen die Gefährdung durch ultraviolette Strahlung.)

" Proposals from the British X-Ray and Radium Protection Committee to be submitted for International Approval by the Second International Congress of Radiology designed to unify Protective Measures and to improve the Working Conditions in All Countries. "

Stockholm, 1928, A.B. Hasse w. Tullbergs Boktryckeri.

France.

Article 16 of the Law of November 30th 1892. (Punishment of unlawful practice of medicine), amended, March 29th, 1929.

Germany.

" Merkblatt der Deutschen Röntgengesellschaft über den Gebrauch von Schutzmassnahmen gegen Röntgenstrahlen vom Jahre 1926. "

Fortschritte Röntgenstrahlen, Vol. 34, p. 848, 1926.
Strahlentherapie, Vol. 23, p. 193, 1926.

" Vorschriften für die Erreichtung und den Betrieb von medizinischen Röntgenanlagen zur Vermeidung von Schädigungen durch Röntgenstrahlen und chemische Wirkungen. " (DIN-Röntgen-Normen.)

Vorschlag I. Einspruchsfrist bis 1. September 1928.

" Betriebsvorschriften für medizinische Röntgenanlagen. "
Normenstelle der Deutschen Röntgengesellschaft.
Fortschritte Röntgenstrahlen, Vol. 39, p. 744, 1929.

Normenstelle der Deutschen Röntgengesellschaft, Arbeitsgruppe II, " Strahlenschutz "; Bericht über die 1. und 2. Sitzung (2. Dezember 1927 und 20. Januar 1928).
Fortschritte Röntgenstrahlen, Vol. 38, p. 141, 1928.

Bericht über die 3., 4. und 5. Sitzung.
Fortschritte Röntgenstrahlen, Vol. 39, p. 733.

Bericht über die 6. Sitzung.
Fortschritte Röntgenstrahlen, Vol. 41, p. 90, 1930.

" Vorschriften über den Strahlenschutz in medizinischen Röntgenanlagen. " (DIN-Röntgen-Normen.)
Endgültige Fassung. Beuth-Verlag, Berlin, SW. 14, Dresdener Str. 97.
Fortschritte Röntgenstrahlen, Vol. 41, p. 86, 1930 (Vollständiger Wortlaut.)
Strahlentherapie, Vol. 36, p. 393, 1926.

Normenstelle der DRG. Arbeitsgruppe VI, " Röntgenröhren " : Bericht über die 1. Sitzung (23. März 1928).
Fortschritte Röntgenstrahlen, Vol. 37, p. 919, 1928.

Bericht über die 2. Sitzung.
Fortschritte Röntgenstrahlen, Vol. 40, p. 540, 1929.

Bericht über die 3. Sitzung.
Fortschritte Röntgenstrahlen, Vol. 40, p. 1123, 1929.

Germany.

Bürgerliches Gesetzbuch, § 618.

Greece.

Memorandum of the Greek Ministry of Public Health appointed to study the Legislative Measures to be taken for Protection against the Dangers of X-Rays and Radium.

Submitted to the Health Organisation of the League of Nations. (League of Nations, document C.H.827.)

Hungary.

RATKOCZI, Budapest : " *On Injuries in X-Ray Laboratories and Protective Measures. Proposals for Legislation providing for the following Protective Measures.*

League of Nations, document C.H.775.

League of Nations. Minutes of the meeting of the Health Committee, documents C.245.M.79.1928.III ; C.3.M.3.1929.III ; A.8.1929.III (C.H.783) ; C.246.M.85. 1929.III.

LEVY-DORN : *Gesetzliche Bestimmungen zur Ausübung des Röntgenverfahrens im Auslande.*

Referat aus dem Sonderausschuss für die Beurteilung von Röntgenschädigungen und zum Studium ihrer Verhütung. 27. April 1927.

Fortschritte Röntgenstrahlen, Vol. 36, p. 410.

Italy.

Communication of the Director-General of Public Health in the Ministry of the Interior, March 1929.

Norway.

Duties and Rights of the Physicians and Dentists. Law of January 1st, 1928.

Spain.

A yuntamiento constitucional de Madrid, Capitulo IXbis. " Instalaciones de electro-radiologia medica. "

Gaceta de Madrid, Núm. 219, 1927.

Sweden.

" Proposals from the Swedish X-Rays and Radium Protection Committee. " Second International Congress of Radiology. Stockholm, 23rd-27th of July 1928.

Kungl. Boktryckeriet. P. A. Norstedt & Söner.

Switzerland.

" Instructions pour l'Etablissement et la Direction d'Installations Radiologiques (Rayons Roentgen). "
Société Suisse de radiologie, 1928.

The Netherlands.

JITTA, N. M. et VAN DER PLAATS (Utrecht) :
L'emploi des rayons X et le danger qui peut en résulter.

Mémorandum adressé à l'Organisation d'hygiène. (Société des Nations, document C.H.174.)

Union of Soviet Socialist Republics.

Verfügung des " Volkskommissariats der Arbeit " der Räterepublik vom 9. September 1925. Nos. 233/389 betreffs des Arbeitsschutzes der in Röntgenkabinetten tätigen Arbeiter.
Fortschritte Röntgenstrahlen, Vol. 35, p. 781, 1927.
Annales de Roentgenologie et Radiologie, Vol. II, p. 148, 1926.

United States of America.

Chicago, Ill. Prescriptions for Laboratories. Amendments for the Chicago Code of 1911. Ords. April 7th, 1920, and April 8th, 1921.

New York. Amendments to the New York Regulation (concerning X-Ray Laboratories). July 24th, 1923, and February 26th, 1926.

Porto Rico. Act. No. 62 approved May 1st, 1928 (X-Ray Laboratories).

* * *

Albers-Schönberg : " Institute und Laboratorien, ihre Organisation, Leitung und Verwaltung. "
Aus Albers-Schönberg, *Röntgentechnik.* III. Auflage, p. 280, 1910.

Albers-Schönberg und Lorenz : " Die Schutzmittel für Ärzte und Personal bei der Arbeit mit Röntgenstrahlen. "
Deutsche medizinische Wochenschrift, No. 11, 1915.

Allen, S. I. M. : " Die Absorption der Röntgenstrahlen bis herab zu den Wellenlängen von 0,08 AE. "
Physical Review, 24, 1 (1924); 27, 266 (1926) ; 28, 907 (1926).

Altschul, W. : " Internationale Strahlenschutzbestimmungen. "
Strahlentherapie, Vol. 24, p. 766.

Arnell, S. : " A Plastic Means of Protection for the X-Ray Treatment. "
Acta Radiologica, III, p. 66, 1924.

" Arrangements for Protection in Roentgen and Radium Work. "
Acta Radiologica, III, p. 422, 1924.

Baastrup, Chr. J. : " Einige Bemerkungen über die Bedingungen röntgenologischer Tätigkeit in Dänemark. "
Ugeskrift for Laeger, 1927, p. 87.

Bachem : " Der gegenwärtige Stand des Problems der Röntgenstrahlendosierung. "
Arch. of Physical Therapy, X-Ray, Radium, Vol. 7, p. 151.

Baensch, W. : " Besserer Strahlenschutz für die Hände des Röntgenologen. "
Röntgenpraxis, Vol. III, chap. 6, p. 286, 1931.

Barclay, A. E., and Cox, Sidney, (übersetzt von Otto Risse, Stuttgart) : " Die Strahlengefährdung des Röntgenologen. Ein Versuch, die in der Diagnostik verwendeten Röntgenstrahlenmengen zu messen und ihre Gefahren abzuschätzen. "
Fortschritte Röntgenstrahlen, Vol. 38, p. 311, 1928.

Barclay, A. E., Stead, G. and Cox, S. F. : " A Source of Error in the Measurements of Dosage. "
British Journal of Radiology, II, p. 401, 1929.

Béclère, A. : " Sur l'unification internationale des mesures de dosage en roentgenthérapie. "
Premier Congrès international de radiologie, Londres, 1925.
Journal de Radiologie, t. X, p. 125.
Strahlentherapie, Vol. 21, p. 468, 1928.
(Übersetzt von Dr. G. Wittigschlager-Bremen.)

Béclère, A. : " La discordance des mesures pour l'évaluation de l'unité de dose radiothérapique en Allemagne et aux Etats-Unis. "
Journal de Radiologie, t. XI, p. 535.

Behnken, H. : " Zur Frage der Röntgendosiseinheit. "
Strahlentherapie, Vol. 29, p. 192.

" Dosimetrische Untersuchungen über Röntgenstrahlenschutz und Strahlenschutzröhren. "
Fortschritte Röntgenstrahlen, Vol. 41, p. 245, 1930.

Behnken, H., und Jaeger, R. : " Die Standardisierung der Röntgenstrahlendosis. "
Radiology, Vol. X, p. 275, 1928. Ref. *Zentralbl. Radiologie*, Vol. V, p. 322.

Behnken, H. : " Die Absolutbestimmung der Dosiseinheit ' 1 Röntgen ' in der Physikalisch-Technischen Reichsanstalt. "
Strahlentherapie, Vol. 26, p. 79, 1927.

Belot, J. : " Paravent protecteur du docteur J. Belot. "
Bul. Soc. Radiol. méd., France, XVIII, 120-124.
Ref. *Zentralblatt für Radiologie*, IX, 15.

Belot, M. J. : " Sur les cupules protectrices pour radiothérapie pénétrante avec tubes dans l'air. "
Journal de Radiologie, VIII, p. 363.

Belot, J. : " Apparat zum Schutz bei der Durchleuchtung bei vertikaler Körperstellung. "
Acta Radiologica, Vol. X, p. 221.

BELOT, J. : " Ein Apparat mit ' vollständigem Schutz ' bei röntgenologischen Untersuchungen in aufrechter Stellung. "

Arch. electr. méd. Mars-Avril 1929, 545, p. 125.
Ref. *Fortschritte Röntgenstrahlen*, Vol. 40, p. 709.

BENNER, Sven : " Über die Schwächung der Radiumstrahlen durch die Wände und die Fussböden in Gebäuden. "

Acta Radiologica, Vol. XI, p. 310.

BERNSTEIN, A. und KLOSE, Wilhelm : " Schutz gegen Röntgen-Nebenstrahlung bei Röntgendurchleuchtungen. "

Fortschritte Röntgenstrahlen, Vol. 38, p. 107.

BERTHOLD : " Über die Wirkung von Röntgenschutzstoffen. "

Strahlentherapie, Vol. 16, p. 147, 1924.

BERTHOLD und GLOCKER : " Über die Strahlenschutzwirkung von Baustoffen. "

Strahlentherapie, Vol. 16, p. 507, 1924.

" Berufung eines Physikers auf die Lehrkanzel für Röntgenologie " (mit Bemerkungen HOLZKNECHTS).

Fortschritte Röntgenstrahlen, Vol. 33, p. 841.

BOUCHACOURT et MOREL-KAHN : " De quelques points fondamentaux, concernant la protection des personnes utilisant les rayons X. "

Bulletin et Mém. de la Soc. de radiol. méd. de France, année XVI, p. 59, 1928.
Ref. *Zentralbl. Radiologie*, V, p. 201.

BOUCHARD : " Bericht betreffend die gesetzliche Regelung der medizinischen Anwendung der Röntgenstrahlen. "

Arch. d'Electr. méd. No. 264.
Ref. *Fortschritte Röntgenstrahlen*, Vol. XIV, p. 221.

BOUWERS, A. : " A New X-Ray Apparatus with Complete X-Ray and Electrical Protection. "

Acta Radiologica, Vol. IX, p. 600, 1929.

" Eine Metallröntgenröhre mit drehbarer Anode. Mit Aussprache. " Deutsche Röntgengesellschaft, Wien, 1929.

Fortschritte Röntgenstrahlen, Vol. 40, Kongressheft p. 102.

BOUWERS, A. und VAN DER TUUK, J. H. : " Strahlenschutz. "

Fortschritte Röntgenstrahlen; Vol. 41, p. 767.

BOWEN : " Über Bleigummischürzen. "

American Journal of Roentgenology, Vol. XVI, p. 473, 1926.

Bowes, Phyllis K. : " Notes on X-Ray Protection. "

The British Journal of Radiology, No. 296, XXX, 1925.

Braun, R., Hase, H., und Küstner, H. : " Über die in der Röntgendiagnostik verabfolgten Dosen in R-Einheiten. "

Fortschritte Röntgenstrahlen, Vol. 38, p. 385, 1928.

Carelli, H. H., und Vierheller, Fr., (Buenos Aires) : " Vergleich zwischen deutschen und französischen Einheiten. "

Strahlentherapie, Vol. 21, p. 468.

Chantraine, H., und Profitlich, P. : " Über den Schutz des Ärztes und seiner Gehilfen vor den Röntgenstrahlen. "

Fortschritte Röntgenstrahlen, Vol. 38, p. 121.

" Über die Messung der Spannung bei ganz hohen Milliampère-Zahlen. "

Fortschritte Röntgenstrahlen, Vol. 41, p. 44.

Charlier, A. : " La protection contre les rayons X. "

Bull. et Mém. de la Soc. de Radiologie Méd. de France, Année XVI, p. 65, 1928.
Ref. *Zentralbl. Radiologie*, V, p. 291.

Compton, *Handbuch der Physik*.

Herausgegeben von Geiger und Scheel, Vol. 23, p. 425.

Cramer, H., und Borm, A. : " Das neue Bestrahlungsgerät der Metalix-Therapieröhre Filmvortrag, gehalten auf dem Röntgenkongress in Wien. "

Strahlentherapie, V. 33, S. 156.

Dauvillier, A. : " Le dosage des rayons X. "

Journal de Radiologie et d'Electrologie, Vol. XI, p. 149, 1926.
Le Cancer, IV^e^ année, N° spécial, p. 168, 1927.
Ref. *Zentralbl. Radiologie*, IV, p. 564.

Dauvillier, A., Laborde, A., et Saget, J. : " Sur la réalisation de l'unité *r* internationale et l'étalonnage absolu des dosimètres radiologiques. "

Journal de Radiologie, XIII, p. 433.

Desjardins, A. U. : " Protection against Radiation. "

Radiology, I, p. 221.

Dieterich, W. : " Fehlerquellen in der Apparatur und Dosimetrie und ihre praktische Auswertung. "

Fortschritte Röntgenstrahlen, Vol. 36, p. 183, 1927.

Dietlen, H. : " Vorschlag zur Einschränkung der Gefahr von Röntgenschädigungen und zur Gewinnung eines einheitlichen Dosierungsverfahrens. "

Münchner Med. Wochenschr., 1920,, p. 1355.

" Diskussion über Standardisierungsfragen. " I. Internationaler Röntgenkongress. London, 1925.

Ber. Geb. u. Gyn., XII, p. 744.

Eder und Freund : " Ein neues Schutzmittel gegen Lichtschäden. "

Wiener klinische Wochenschrift, 1922, p. 681.

Eggert, J., und Luft, F. : " Ein neuartiges Filmdosimeter. "

Röntgenpraxis, Vol. I, p. 187, 1929. II. Mitt. p. 655.

Ellis und Wooster : *Handbuch der Physik*, herausgegen von Geiger und Scheel. Vol. 22, p. 217, 1926.

Engelbrecht-Erlangen : " Ein strahlensicheres Kompressionsstativ " (Wintz-Kanone). Filmvorführung. Röntgenkongress, 1924.

Fortschritte Röntgenstrahlen, Vol. 32, Kongressheft, p. 218.

Ernst, E. C., Glasser, O., Stenstrom, W., Dorsey, N. E., Hunt, F. L., Chamberlain, W. E., Erskine, A. W. : " Preliminary Report of the Committee on Standardisation of X-Ray Measurements. "

Radiology, Vol. VI, p. 191.

Forssell, G. : " Barium Porcelain ; a New Protective Material against the Röntgen Rays. "

Acta Radiologica, III, p. 249.

Foveau de Courmelles : " Radioanaphylaxie. "

Arch. d'Electr. Méd. et de Physiothérapie, No. 482, Nov. 1922, p. 327.
Fortschritte Röntgenstrahlen, Vol. 31, p. 129.
" Pour les victimes des radiations. "

Gazette des hôp. civ. et milit., XCIX^e^ année, p. 1483, 1926.
Ref. *Zentralbl. Radiologie*, Vol. IV, p. 357.

Fricke, H., and Beasley, I. E. : " Measurement of the Stray Radiation in Roentgen-Ray Clinics. "

Ref. : *American Journal of Roentgenology and Radium Therapy*, Vol. XVIII, p. 146, 1927.

Fried, Carl : " Ein neues Bestrahlungsgerät in Verbindung mit der Metalix-Therapieröhre. "
Strahlentherapie, Vol, 33, p. 160.

Friedrich, W., und Glasser, O. : " Untersuchungen und Betrachtungen über das Problem der Dosimetrie. "

Strahlentherapie, 1923, Vol. 14, p. 362.

Friesleben, M. : " Röntgenschädigungen beim Hilfspersonal. "

Deutsche medizinische Wochenschrift, p. 1680, 1929.

Frik, K. : " Filterbemessung bei Röntgendurchleuchtungen und -aufnahmen. "

Fortschritte Röntgenstrahlen, Vol. 34, p. 180.

FRIK, Karl, und LEVY-DORN, Max : " Die beim Arbeiten mit Röntgenstrahlen auftretenden Gefahren und ihre Verhütung. "

Deutsche Zeitschrift für öffentliche Gesundheitspflege, 3rd Year, p. 147, 1927.

FRITSCH, E. : " Dosierungsfehler bei Röntgenbestrahlungen infolge Falschzeigens des Milliamperemeters und deren Vermeidung. "

Strahlentherapie, Vol. 24, p. 719.

FÜRST, W. : " Zur Sicherung des Bedienungspersonals von Röntgenapparaten gegen tödliche Unfälle und zur Frage der Verantwortlichkeit. "

Strahlentherapie, Vol. 21, p. 508, 1926.

" Aus einem Gutachten über die Notwendigkeit der Anschaffung eines Dosimessers "

Röntgenpraxis, II, p. 908, 1930.

GAUSS, C. J. (zu Strahlenschutz) : *Lehrbuch der Strahlentherapie*. Herausgegeben von H. Meyer und C. J. Gauss, Vol. IV, 1, p. 374.

GLASSER, O. : " Die Absolutbestimmung der Dosiseinheit " 1 Röntgen " in der Eichstation der Cleveland Clinic. "

Strahlentherapie, Vol. 27, p. 160.

" Einige Betrachtungen zum Problem der Strahlendosimetrie. "

Strahlentherapie, Vol. 27, p. 740, 1928.

GLASSER, O., and PORTMANN, U. V. : " The Standardisation of the Roentgen-Ray Dose. "

The American Journal of Roentgenology and Radium Therapy, Vol. XIX, p. 47, 1928.

GLOCKER : " Über den Strahlenschutz. "

Die Naturwissenschaften, 12th Year, p. 169.

GRASHEY und MITARBEITER : *Irrtümer der Röntgendiagnostik und Röntgentherapie, der Lichtbehandlung und der Radiumtherapie.*

Verlag G. Thieme, Leipzig, 1924.

GLOCKER, R. : " Über den Strahlenschutz. "
Die Naturwissenschaften, 12th Year, p. 169.

Strahlenschutz und Anlage von Röntgenabteilungen. Ergebnisse der medizinischen Strahlenforschung.

Herausgegeben von H. Holfelder, H. Holthusen, O. Jüngling, H. Martius, H. R. Schinz. Vol. I, p. 365.

" Internationale Strahlenschutzbestimmungen. "

Strahlentherapie, Vol. 22, p. 193.
Fortschritte Röntgenstrahlen, Vol. 34, Kongressheft.

" Zur Frage der ' Bleischutzdicken ' in den internationalen und in den deutschen Strahlenschutzvorschriften. "
Fortschritte Röntgenstrahlen, Vol. 41, p. 967.

Glocker, R., und Reuss, A. : " Strahlenschutzmessungen. "
Fortschritte Röntgenstrahlen, Vol. 40, p. 501, 1929.

" Strahlenschutzmessungen II. "
Fortschritte Röntgenstrahlen, Vol. 42, p. 651.

Glocker, R., und Kaupp, E. : " Über den Strahlenschutz und die Toleranzdosis. "
Strahlentherapie, Vol. 20, p. 144, 1925.

Graf, H. : " Was muss der Arzt über die Auswirkung der neuen Hochspannungs- und Strahlenschutzvorschriften wissen ? "
Medizinische Welt, p. 1228, 1930.

Grebe : " Die energetische Bedeutung der R-Einheit. "
Strahlentherapie, Vol. 22, p. 438.

Grebe, L., und Martius, H. : " Die Standardisierung der Röntgenstrahlenmessung. "
Deutsche medizinische Wochenschrift, p. 1156, 1926.

Grebe, L., und Gaertner, O : " Die absolute Herstellung der R-Einheit im Bonner Röntgeninstitut. "
Strahlentherapie, Vol. 27, p. 728, 1928.

Grebe, L., und Martius, H. : " Zur Standardisierung der Röntgenstrahlenmessung. "
Deutsche medizinische Wochenschrift, p. 1156, 1926.

Gunsett, A., und Nourettine O, C. : " Etudes ionométriques sur la dose additionnelle de diffusion. "
Journal de Radiologie, Vol. 14, p. 551, 1930.

Habs, H. : " Die Gefahr des Palpierens mit der ungeschützten Hand. "
Fortschritte Röntgenstrahlen, Vol. 42, p. 779.

Hase, H., und Küstner, H. : " Über die Wahrung der R-Einheit. "
Strahlentherapie, Vol. 29, p. 745, 1928.

Heimroth, Otto : " Über die zweckmässige Einrichtung von Röntgenanlagen unter besonderer Berücksichtigung des Röntgenschutzes für das Bedienungspersonal. "
Deutsche zahnärztliche Wochenschrift, p. 632, 1930.
Zentralblatt Radiologie, Vol. IX, p. 351.

Heitz : " Zur Filtersicherung. "
Strahlentherapie, Vol. 15, p. 684, 1923.

" Beitrag zur Filtersicherung. "
Fortschritte Röntgenstrahlen, Vol. 36, Supplement, p. 104, 1927.

Herrmann, H., und Jaeger, R. : " Über eine Röntgenapparatur für ca. 400 kV Röhrenspannung. "
Fortschritte Röntgenstrahlen, Vol. 41, p. 426.

" Bleiabsorptionsmessungen an extrem harten Röntgenstrahlen. "
Fortschritte Röntgenstrahlen, Vol. 42, p. 115.

Halberstaedter, L., und Tugendreich, J. : " Die Bedeutung der die Röntgenröhre rückwärts verlassenden Strahlung und die Notwendigkeit einer geeigneten Schutzvorrichtung. "

Med. Klinik, No. 9, 1921.

Heuser, C. : " Regeln für den Schutz gegen Röntgenstrahlen. "

Semana méd., 33rd Year, p. 362, 1926.
Zentralbl. Radiologie, Vol. III, p. 303.

Hoffmann, W. : " Über Augenschutz bei Anwendung von Röntgen- und Radiumstrahlen. "

Strahlentherapie, Vol. 36, p. 105.

Holfelder, H.: " Ein neues strahlensicheres Bestrahlungsgerät für die Tiefentherapie. "
Fortschritte Röntgenstrahlen, Vol. 34, Kongressheft, p. 178.

Holfelder, H., und Körte, W. : *Das Röntgeninstitut der chirurgischen Universitäts-Klinik im städtischen Krankenhaus Sachsenhausen in Frankfurt/M. 1929.* (Im Buchhandel.)

Holmsen, R. : " The Need of Some Simple Uniform Safety Regulation for the Installation of Röntgen Plants. "

Acta Radiologica, Vol. IV, p. 6.

Holthusen, H. : " Über die Standardisierung der Röntgendosismessung. "
Fortschritte Röntgenstrahlen, Vol. 34, Kongressheft, p. 156.

" Der derzeitige Stand der physikalischen Messmethoden. "

Strahlentherapie, Vol. 22, pp. 1-37, 1926.

Holzknecht, G. : " Schutz der Umgebung der Bestrahlungsfelder bei der Röntgenbehandlung. Leuchtendes Blei. "

Fortschritte Röntgenstrahlen, Vol. 34, p. 169, 1926.

" Schädigungsprophylaxie. "

Strahlentherapie, Vol. 24, p. 385.
Wiener med. Wochenschrift, No. 42, 1927, p. 1419.

" Zur Frage der gesetzlichen Sicherheitsbestimmungen für die Anwendung von Röntgenstrahlen. "

Fortschritte Röntgenstrahlen, Vol. 37, p. 82. *Berichtigung*, p. 266. *Wiener klin. Wochenschr.*, 1926.

Hunt, F. L. : " Barium Sulphate as a Protective Material against Roentgen Radiation. " (National Bureau of Standards.)

The American Journal of Roentgenology and Radium Therapy, Vol. XIV, p. 524.

Hunt, F. L., and Temin, Morris : " X-Ray Protective Plasters. "
Radiology, February 1927, p. 117.

Immelmann, X. : " Vorschriften für Röntgengehilfinnen zur Vermeidung von Röntgenschädigungen. "
Röntgenhilfe, 1921, 1st Year, No. 1.

Irle und Bergerhoff : " Selbsttätige elektrische Sicherung gegen Verwechseln und Vergessen der Strahlenfilter (D.R.P.a). "

Strahlentherapie, Vol. 22, p. 562, 1926.

" Vereinigte Filtersicherung and Röntgenapparaten mit vereinigtem Filterwähler und Zeitwähler (D.R.P.a). "

Strahlentherapie, Vol. 23, p. 181, 1926.

Irle : Aussprache, Röntgenkongress 1926.

Fortschritte Röntgenstrahlen, Vol. 34, Kongressheft, p. 182.

Ishino : *Philosophical Magazine*, Vol. 35, p. 129, 1917.

Jacobson, L. E. : " Measurement of Stray Radiation in Roentgen-Ray Clinics of New York City. "

Amer. Journ. of Roentg. and Radium Ther. Vol. XVIII, p. 149, 1927.
Internationale Radiotherapie, Vol. III, p. 743.

Järnh, B. E. : " Eine neue Schutzkappe für Tiefentherapie. "

Acta Radiologica, Vol. VII, p. 6, 1926.

Jaeckel, G. : " Über den Strahlenschutz bei Röntgenstationen. "

Fortschritte Röntgenstrahlen, Kongressheft, Vol. 34, p. 179, 1926.

Jaeger, R. : " Zur Frage der Röntgendosiseinheit ' R ' in der Therapie. "

Internationale Radiotherapie, II, p. 770, 1927.

" Die Bedeutung der Röntgendosiseinheit ' R ' für die Therapie. "

Internationale Radiotherapie, Vol. I, p. 807, 1926.

Janker, R. : " Eine einfache Massnahme zur Verhütung von Überdosierungen bei Durchleuchtungen, besonders bei Magen-Darmuntersuchungen. "

Röntgenpraxis, I, p. 46, 1929.

Janus, F. : Können aus Glühventilröhren unter Umständen Strahlen austreten, die einen besonderen Schutz notwendig machen ? "

Fortschritte Röntgenstrahlen, Vol. 35, p. 381, 1926.

Jaulin : " Rapport sur les dangers des rayons X et des substances radioactives pour les professionnels ; moyens de s'en préserver. "

Journal de Radiologie, Vol. XI, p. 193.

Jerman, E. C. : " Protection from an X-Ray Standpoint. "

Radiology, Vol. V, p. 430.

Jona, M. : " Das Problem der Dosierung in der internationalen Röntgen- und Radiumtherapie 1924 bis Mitte 1926. "

Internationale Radiotherapie, Vol. I, p. 812.

Kaye, G. W. C. : " Discussion on X-Ray and Radium Protection and Appliances. X-Ray Protective Measures. " First International Congress of Radiology, London, June 30th-July 4th, 1925.

British Journal of Radiology (Journal of the Röntgen Society), Vol. 23, No. 91, pp. 155, 168, 1927.

" Schutz und Arbeitsbedingungen in Röntgenabteilungen. "

Brit. Journ. Radiol. (new series), Vol. I, 9, p. 295.
Fortschritte Röntgenstrahlen, Vol. 39, p. 187, 1929.

" Grundlegende Betrachtungen über Röntgenstrahlen und über den Strahlenschutz für den Röntgenoperateur. " (" Some Fundamental Aspects of Roentgen Rays and the Protection of the Roentgen-Ray Worker. ")

American Journal of Roentgenology and Radium Therapy, Vol. XVIII, p. 401, 1927.
Zentralblatt Radiologie, Vol. V, p. 291.

Kirchberg : " Die Pflichten der Krankenhausdirektoren gegen ihre Röntgenassistenten und Angestellten. "

Fortschritte Röntgenstrahlen, Vol. IX, p. 307.

Kirchner : " Allgemeine Physik der Röntgenstrahlen. "

Handbuch der experimentellen Physik, Vol. 24, p. 113.

Koch und Sterzel, A.-G. : " Filtersicherungen für Röntgeneinrichtungen. DRP., 452, 292, 1927. "

Zentralblatt Radiologie, Vol. IV, p. 564.

Köhler, Alban : " Zur Verantwortung des Vorgesetzten für den Schutz seines Röntgenpersonals. "

Deutsche medizinische Wochenschrift, No. 43, 1912.

Kohlrausch : *Probleme der Gammastrahlung.*

Verlag Vieweg und Sohn, Braunschweig, 1927.

Krause, P. : " Wie schützt der Arzt bei Durchleuchtungen seine Kranken und sich selbst vor Schädigungen durch Röntgenstrahlen ? "

Münchner Medizinische Wochenschrift, p. 985, 1923.

Kruchen, C. : " Filtersicherung. "

Strahlentherapie, Vol. 19, p. 741.

Kupferberg : " Die Technik der Radiumstrahlung. Selbstschutz des Therapeuten. "

Lehrbuch der Strahlentherapie, Vol. IV, Part I, p. 507, 1929.

Küstner, H.: " Die Absolutbestimmung der R-Einheit mit dem grossen Eichstandgerät."

Strahlentherapie, Vol. 27, p. 331.

Lammers, H. A. M. M. : " Über die der Strahlenbehandlung anhaftenden Gefahren. "

Nederl. Tijdschr. v. Geneesk. 1924, I, p. 2790.
Ref. : *Zentralblatt für Innere Medizin*, p. 801, 1924.

Landauer, R. S. : " Die Anwendung von Zahnfilmen zur Bestimmung von Streustrahlen. "

Radiology, Vol. VII, p. 512. *Fortschr. Röntgenstr.* 36, p. 1319, 1927.

Lauritsen und Bennet : *Physical Review*, Vol. 32, p. 850, 1928.

LAURITSEN und CASSEN : “ High Potential X-Ray Tube. ”
Physical Review, Vol. 36, p. 988, 1930.

LEDOUX-LEBARD et DAUVILLIER : *Physique des rayons X*. Paris, 1921.

“ Leitsätze für das Arbeiten mit Röntgenstrahlen gemäss Beschluss der Deutschen Röntgengesellschaft vom 28 April 1924. ”
Deutsche Zeitschrift für die gesamte gerichtliche Medizin, Vol. 4, chap. 3, 1924.

LEVY-DORN, M. : “ Wie lange dürfen einem Arzt Durchleuchtungen mit dem Fluoreszenzschirm zugemutet werden ? ”
Röntgenhilfe, 1922, No. 6.

LEWIN, H. : “ Schutzvorrichtung gegen Streustrahlen. ”
Fortschritte Röntgenstrahlen, Vol. 36, p. 144, 1927.

LOREY, A. : “ Der Röntgenstrahlenschutz. ”
Lehrbuch der Strahlentherapie, Vol. I, p. 1101, 1925.

LOSSEN, H. : “ Entstehung und Verhütung der Unfälle und Schäden in medizinischen Röntgenlaboratorien. ”
Monatsschrift für Unfallheilkunde, 1926, Nos. 8 and 9.
Ref. *Zentralblatt Radiologie*, Vol. II, p. 797.

LUNDQVIST, A. : “ Über eine besondere Schutzmassregel für die Manipulation mit Radiumpräparaten. ”
Acta Radiologica, Vol. IX, p. 119, 1929.

MARAGLIANO : “ Schutz bei Durchleuchtung. ” Ital. Röntgenkongress 1926 (Bericht).
Fortschritte Röntgenstrahlen, Vol. 36, p. 181, 1927.

MARKOVITS : “ Röntgenschutz. ”
Medizinische Klinik, p. 866, 1923.

MARTIUS, H. : “ Die Röntgenstrahlenmessung in R-Einheiten. ”
Acta Radiologica, Vol. VII, p. 193, 1926.

MEYER, P. S. : “ Über Schutzmittel gegen Ultraviolettlicht und Röntgenstrahlen. ”
Zschr, f. physikalische Therapie, Vol. 30, p. 261, 1925.

MEYER und GLASSER : “ Erythemdosen in absoluten Einheiten. ”
Radiology, Vol. VI, p. 320, 1926.

MIESCHER, G. : “ Strahlenschutz und Lichtgewöhnung. ”
Klinische Wochenschrift, p. 840, 1929.

MOSES, P. : “ Bemerkung zu der Arbeit Chantraine und Profitlich : “ Über den Schutz des Arztes und seiner Gehilfen auf dem Gebiete der Röntgenstrahlen ”, Vol. 38, Chap. I.
Fortschritte Röntgenstrahlen, Vol. 38, p. 698, 1928.

MÜLLER, E. H. : “ Zur Frage der Zeitkontrolle im medizinischen Röntgenbetrieb ”.
Fortschritte Röntgenstrahlen, Vol. 42, p. 657.

Murdoch, J., und Stahel, E. : " Vergleichende Studie von zwei dosimetrischen Röntgeneinheiten — das französische R (Solomon) und das deutsche R (Behnken) ".
Strahlentherapie, Vol. 27, p. 561.
Archives d'Électricité Médicale et de Physiothérapie du Cancer, Vol. 35, N° 525, mars-avril 1927.

Mutscheller, A. : " *Physical Standards of Protection against Roentgen-Ray Dangers* ".
The American Journal of Roentgenology, Vol. XIII, p. 65.

" Further Studies of Physical Standards of Protection against Roentgen-Ray Dangers ".

Radiology, Vol. VI, p. 314.

" Safety Standards of Protection against X-Ray Dangers. "
Radiology, Vol. X, p. 468.

" Niederösterreichische Statthalterei : Verordnung, betreffend die Bedingungen für die Errichtung und den Betrieb von Instituten für Radiographie und Radiotherapie. "

Münchner Medizinische Wochenschrift, p. 208, 1900.

Neeff, Th. : " Über den Strahlenschutz und die Verbesserung seiner Wirkung. "
Strahlentherapie, Vol. 24, p. 161, 1926.

" Über Strahlendosen in der Diagnostik. "
Internation. Radiologenkongress, Stockholm, 1928.

Acta Radiologica, Suppl. III, Part II, p. 197, 1929.
Fortschritte Röntgenstrahlen, Vol. 41, p. 414 (ausführlich).

Neugebauer, F. : " Sicherungsschloss gegen Filterverwechseln. "
Fortschritte Röntgenstrahlen, Vol. 35, p. 975, 1927.

Nölke, W. : " Gefahren in Röntgenbetrieben durch falschanzeigende Messinstrumente. "
Röntgenpraxis, Vol. I, p. 271.

Norway. — " Protection Committee of ' Norsk Forening for Medicinsk Radiologi '. Arrangements of Protection in Röntgen and Radium Work. " Sitzungsbericht.
Internationale Radiotherapie, Vol. I, p. 69.

Pagenstecher : " Über neue Röntgenschutzmittel. "
Fortschritte Röntgenstrahlen, Vol. 36, p. 719, 1927.

Pfahler, G. E. : " The Dangers in Roentgenology and Radium Therapy ".
The American Journal of Roentgenology and Radium Therapy, Vol. XIII, p. 276, 1925.
Radiology. Vol. II, p. 106 (Editorial).

" A Device to prevent the Omission of a Filter in Deep Roentgen Therapy ".
The American Journal of Roentgen Therapy, Vol. X, p. 562, 1923.

Pilon, H. : " Discussion on X-Ray and Radium Protection and Appliances. Protection in Radiotherapy ". First International Congress of Radiology, London, 1925.
Brit. Journ. of Radiology (Journal of the Röntgen Society), Vol. 23, p. 164, 1927
Ref. *Zentrahlbl. Radiologie*, Vol. III, p. 358.

Plaats, B. J. van der, und van der Plaats, G. J. : " Strahlenschutzröhren bei der Durchleuchtung. "

Fortschritte Röntgenstrahlen, Vol. 39, p. 496.

Pohle, E. A. : " Begrenzte Exposition in der Strahlenuntersuchung. "

Radiology, Vol. IX, p. 64. Ref. *Fortschritte Röntgenstrahlen*, Vol. 36, p. 1314.

Polgar, F. : " Tödlicher elektrischer Unfall in einem Röntgenlaboratorium. "

Med. Klinik, p. 453, 1926.

" Protection of X-Ray Workers ".

British Journal of Radiology (Journal of the Röntgen Society), Vol. 22, p. 45, 1926. Ref. *Zentralblatt Radiologie*, Vol. I, p. 781.

Pugno-Vanoni, E. : Röntgenschutzschirme ohne Eigenstrahlung. "

La Radiologia Medica, Vol. 14, p. 782, 1927.
Ref. *Fortschritte Röntgenstrahlen*, Vol. 37, Chap. 1.

" Radiologues. Pathologie professionnelle et hygiène. " (Die berufliche Pathologie und Hygiene der Radiologen.) Nach einem Originalbericht von Prof. E. Perussia-Mailand.

Hygiène du Travail, N° 131.

Rajewsky, B. : " Zur Frage der Dosierung von Röntgenstrahlen. Die Standardisierung der Dosismessung. "

Fortschritte Röntgenstrahlen, Vol. 34, p. 62, 1926.

Ravenel, L. J. : " A Revolving Filter for Use in Roentgen Therapy ".

American Journal of Roentgenology and Radium Therapy, Vol. XXII, p. 171.

" Regulativ für Röntgenlaboratorien von dem Röntgenkomitee einer medizinischen Gesellschaft eines Bezirks (County). "

Radiology, Vol. VIII. March, 1927.
Ref. *Fortschritte Röntgenstrahlen*, Vol. 35, p. 1344, 1927.

Reich : Über Schäden und Unfälle in Röntgenbetrieben.

Wiener klinische Wochenschrift, p. 61, 1929.

Reinberg und Kupritz : " Gewerbliche Schädigung bei der Herstellung von Röntgenröhren in der (Leningrader) Elektrovakuumanstalt. "

Gigiena truda, Nos. 7/8, p. 59.
Ref. *Internationale Radiotherapie*, Vol. II, p. 59.

Reiniger, Gebbert und Schall: " Sicherheitseinrichtung bei Röntgenanlagen. " DRP., 450, 993, 1927.

Zentralblatt Radiologie, Vol. IV, p. 564.

" Report of the Committee on Standardisation of X-Ray Measurements of the Radiological Society of North America. "

Radiology, Vol. X, p. 313, 1928.

RIGELE, H. : " Technik des Strahlenschutzes in Therapie und Diagnostik. "
Strahlentherapie, Vol. 24, p. 762.

RIGLER, L. G. : Beschreibung einer Methode zum Schutz gegen die Strahlen. "
Acta Radiologica, Vol. IX, p. 117.

ROCCHI, G. : " Mezzi di protezione contro le radiozioni nella radium e roentgenterapia. "
Archivio di Radiologia, I, p. 410, 1925.

LA ROCHE, O.: " La protection contre les rayons X et l'électrocution. " (Film der Firma Gaiffe, Gallot et Pilon).
Bull. Soc. Radiol. méd. France, XVIII, 164.
Zentralblatt Radiologie, Vol. IX, p. 16.

ROENA, A. : " El empleo de masa plastica protectora en la terapeutica roentgenologica. "
Revista de Radiologia, II, p. 9.

ROLLESTON, H. : " Über die Wirkungen der Bestrahlung auf Patienten und Röntgenologen und über Schutzmassnahmen. "
British Journal of Radiology (Roentgen Society Section), 1927, Vol. 32, No. 93, p. 266.
Ref. *Fortschritte Röntgenstrahlen*, Vol. 37.

" Über die Wirkungen der Röntgenstrahlen auf Kranke und Röntgenologen, und über Schutzvorrichtungen. "
British Medical Journal, 1927, 3469, p. 9.

ROSENZWEIG, B. K. : " Berufliche Erkrankungen der Röntgenologen und ihre Prophylaxe. "
Fortschritte Röntgenstrahlen, Vol. 36, p. 778, 1927.

RUMP, W. See under WINTZ.

" Energiemessungen an Röntgenstrahlen. "
Zeitschrift für Physik, Vol. 43, p. 254, 1927.

" Die Streustrahlung der Luft. "
Fortschritte Röntgenstrahlen, Vol. 38, p. 58, 1928.

SAGET : " De la protection en radiothérapie profonde. "
Journal Belge de Radiologie, Vol. XII, p. 76.

SALIS, H. VON : *" Über Röntgenschutzstoffe. "*
Fortschritte Röntgenstrahlen, Vol. 34, p. 317.

SALVATORI, G. B. : " Diagnostik-Selbstschutzröhre. "
Archivio di Radiologia, III, p. 455, 1927.
Ref. *Fortschritte Röntgenstrahlen*, Vol. 36.

SANTE, L. R., and HINKLEY, Tracey : " Barium Sulphate Plaster for Protection against 200,000 Volt Roentgen-Rays. "
The American Journal of Roentgenology, XIII, p. 383.

Saupe, E. : " Über die bei diagnostischen Arbeiten verabreichten Röntgenstrahlendosen in R-Einheiten. "

Fortschritte Röntgenstrahlen, Vol. 37, p. 536, 1928.

Schall, W. E. : " Some Engineering Lessons from Stockholm. "

British Journal of Radiology, II, p. 74, 1929.
Zentralblatt Radiologie, Vol. VII, p. 93.

Schechtmann, J. : " Ergebnis der I. allrussischen Konferenz für Organisationsfragen des Röntgenwesens. "

Vestnik rentgenologii i. radiologii, Vol. V, p. 405, 1927.
Zentralblatt Radiologie, Vol. V, p. 241.

" Zur Frage der Festsetzung einer Standardmethode der Dosimetrie. "

Fortschritte Röntgenstrahlen, Vol. 37, p. 916, 1928.

" Die Anwendung des Aspirationsgerätes nach Ebert zur Prüfung des Röntgenschutzes in den Röntgenabteilungen. "

Fortschritte Röntgenstrahlen, Vol. 42, p. 645.

Scheffers, H. : " Raumstrahlung in den Bestrahlungsräumen für Tiefentherapie. "

Strahlentherapie, Vol. 22, p. 726, 1926.

" Strahlenschutz bei Therapie. "

Fortschritte Röntgenstrahlen, Vol, 34, Kongressheft, p. 178, 1926.

Schinz, Fürst, Miescher : " Referate über Röntgen- und Radiumschädigungen. " Thesenvorschlag.

Gesellschaft der Ärzte in Zürich. Ref. *Schweizer Medizinische Wochenschrift*, 1927, p. 601.
Fortschritte Röntgenstrahlen, Vol. 36, p. 948, 1926.

Schlechter, E. : " Streustrahlenschutz in der Diagnostik. "

Fortschritte Röntgenstrahlen, Vol. 34, Kongressheft, p. 178, 1926.
Ebenda, p. 946.

Schmitt : " Schwere Röntgenverbrennungen. "

Münchner Medizinische Wochenschrift, p. 1200, 1922.

Schneller, P. " Über unsere Erfahrungen mit einer Röntgentherapieanlage mit Müller-Metwa-Metalix-Therapieröhre, Deckenstativ und Hammer-Dosimeter. "

Röntgenpraxis, Vol. II, p. 855, 1930.

Schürmayer : " Die Schädigungen durch Röntgenstrahlen und die Bedeutung unserer Schutzvorrichtungen. Röntgenverbrennungen und das theoretische Sachverständigengutachten. "
73. Versammlung Deutscher Naturforscher und Aerzte. Hamburg, September 1901.

Fortschritte Röntgenstrahlen, Vol. V, p. 44, 1901.

Schütz, M. : " Technische Neuheiten auf dem Gebiet der Medizin, öffentlichen Gesundheitspflege und Krankenpflege. "

Deutsche Medizinische Wochenschrift, pp. 1848 and 1934, 1928.

SCOTT, S. G. : " Schutz bei Schirmuntersuchungen. "

British Journal of Radiology (B. I. R. Sect.), Vol. 32, p. 327. *Fortschritte Röntgenstrahlen*, Vol. 36, p. 1319.

SHEARER : " Possible Dangers in Connection with the Use of X-Rays and how to avoid them. "

The Amer. Journal of Roentgenology, Vol. X, p. 240, 1923.

Sicherheit im Röntgenbetrieb.

Lancet, Vol. 210, p. 295.
Ref. : *Zentralblatt Radiologie*, Vol. I, p. 57.

SIEMENS-REINIGER-VEIFA : Gesellschaft für medizinische Technik m. b. H. " Erwiderung auf die Mitteilung der Herren B. J. van der Plaats und G. J. van der Plaats über ' Strahlenschutzröhren bei der Durchleuchtung ' in Band 39, H. 3, S. 496 dieser Zeitschrift. "

Fortschritte Röntgenstrahlen, Vol. 39, p. 905.

SIEMENS-REINIGER-VEIFA : " Filtersicherung für Röntgenröhren. " DRP., 450, 994, 1927.

Zentralblatt für Radiologie, Vol. IV, p. 564.

SIEVERT, R. M. : " Einige Untersuchungen über Vorrichtungen zum Schutz gegen Röntgenstrahlen. "

Acta Radiologica, Vol. IV, p. 61.

" A Circulating Physical Department for standardising the Roentgen Radiation used in Therapy. "

Acta Radiologica, Vol. V, p. 457.

SIEVERT, R., und THORAEUS, R. : " Experimental Measurements of the Lead-Equivalence of Various Building-Materials. "

Acta Radiologica, Vol. XI, p. 331.

SINGER, S. : " Über eine neue Methode der Filtersicherung und einer Ventilation der Röntgenröhre bei therapeutischen Bestrahlungen. "

Fortschritte Röntgenstrahlen, Vol. 35, p. 240.

SIPPEL : " Die Gefahren der modernen Röntgenbestrahlung und ihre Verhütung. "

Zeitschrift für Geburtshilfe und Gynäkologie, Vol. 86, p. 656.

SOILAND, A. : " Protective Factors in Modern High-line X-Ray Work. "

The American Journal of Roentgenology, Vol. X, p. 394, 1923.

" Further Remarks on Protective Measures with Special Reference to the High Voltage. "

Radiology, Vol. II, p. 22.

SOLOMON, I. : *Précis de Radiothérapie profonde*. Masson & Cie, Editeurs, Paris, 1926.

" Recherches sur la valeur des moyens de protection contre l'action à distance des rayons de Roentgen. "

Journal de Radiologie, t. VIII, p. 62, 1924.
Bulletin de l'Académie de Médecine de Paris, t. 110, p. 182, 1923.

" Sur le choix d'une unité quantitométrique internationale. "

Journal de Radiologie, t. X, p. 155, 1926.

" Vergleichende Studie zwischen der französischen und der deutschen 'R-Einheit'. "

Internationale Radiotherapie, Vol. III, p. 779.

" La notation de la quantité de rayonnement en unités R. "

Bulletin de la Société de Radiologie Médicale, Nov. 1927, No. 143, p. 301. *Journal de Radiologie*, t. XII, p. 145.

" Vergleichende Studie von zwei dosimetrischen Röntgeneinheiten — das französische R (Solomon) und das deutsche R (Behnken). " — Erwiderung auf die gleichnamige Arbeit von J. Murdoch und E. Stahel, Brüssel, in Vol. 27 dieser Zeitschrift.

Strahlentherapie, Vol. 29, p. 199, 1928.
Hierzu Erwiderung von H. Behnken.
Ebenda, p. 201.

Spiegler : " Eine Schaltanordnung zum Schutz von Röhre und Patient. "

Zentralblatt Radiologie, Vol. I, p. 457.
Fortschritte Röntgenstrahlen, Vol. 34, Kongressheft, p. 182, 1926.

Strauss, O. : " Über Richtlinien für eine behördlich zu regelnde Konzessionierung der Röntgenbetriebe. "

Fortschritte Röntgenstrahlen, Vol. 37, p. 524.

Tandoja, P. : X-Ray and Radium Protection : Council on Physical Therapy.

Journal Americ. Med. Assoc., Vol. XCII, p. 1428, 1929.

Taylor, L. S. : " Roentgen-Ray Protection ".

American Journal of Roentgenology, Vol. XXII, p. 45.

ten Doornkaat Koolman : " Wirkung der in der Diagnostik verabfolgten Röntgenstrahlenmengen. "

Klinische Wochenschrift, No. 4, p. 169, 1929.

Thoraeus, R. : " How far can Ordinary Milli-Ammeters be used for reading Short-Time Currents ? "

Acta Radiologica, Vol. XI, p. 321.

" Todesfall infolge Überdosierung bei einer Röntgenbestrahlung. "

Ärztliche Mitteilungen von und für Baden, 1924, No. 1.

Ref. *Fortschritte Röntgenstrahlen*, Vol. 31, p. 823.

Tuuk, J. H., van der, und Boldingh, W. H. : " Die Bleischutzdicken in den deutschen Strahlenschutzvorschriften. "

Fortschritte Röntgenstrahlen, Vol. 41, p. 965.

Vienna Letter : " Prophylactic Measures for the Elimination of Dangers incident to the Use of Roentgen-Rays. "

American Journal of Roentgenology, Vol. XXII, p. 267, 1929.

VIOL, Ch. V. : " Protection of Technical Assistants and of those handling Large Quantities of Radium or Radon. "

The American Journal of Roentgenology, Vol. XV, p. 345.

VOLTZ : " Strahlenschädigungen und Strahlenschutz. " Denkschrift, vorgelegt der Hygieneabteilung des Völkerbundes.

VOLTZ, F. : " Ein Zeitregistriergerät für Bestrahlungszwecke. "

Strahlentherapie, Vol. 24, p. 564, 1927.

WALCH, H., DEN HOED, D., und KOOPMAN, L. J. : " Vergleich der absoluten R-Einheit mit der französischen R-Einheit. "

Strahlentherapie, Vol. 29, p. 524, 1928.

WALTER, B. : " In welcher Zeit wird die Erythemdosis unter einem Schutzhandschuh erreicht ? "

Fortschritte Röntgenstrahlen, Vol. 33, p. 231.

WATTERS, R. A. : " Röntgenstrahlenschutz. "

Arch. Physic. Therapy, Vol. 9, p. 553, 1928.

WEBER, E. : " Schädigung des Kranken und des Personals im Röntgenbetriebe und deren Prophylaxe. "

Fortschritte Röntgenstrahlen, Vol. 34, p. 728.

WETTERSTRAND, C. A. : " A Roentgen Accident with a Fatal Result through the Short-Circuiting of the Secondary Current. "

Acta Radiologica, Vol. V, p. 105.

WINTZ, H. : " Röntgenschädigungen in der Tiefentherapie (Kombinationsschäden). " Verhandlungen der Deutschen Röntgengesellschaft 1922.

Fortschritte Röntgenstrahlen, Vol. 30, Kongressheft, p. 133.

" Zur internationalen Standarddosierung. " I. Internationaler Röntgenkongress, Juli 1925. Verhandlungen der Dosierungskommission.

British Journal of Radiology, 1926.

" Aussprache zu dem Vortrag von Haudek (Gefährlichkeit der kleinen Dosen). "

Fortschritte Röntgenstrahlen, Vol. 35, Kongressheft, p. 54.

" Methodik der Röntgentherapie. Strahlenschutz. "

In *Lazarus, Handbuch der gesamten Strahlenheilkunde, Biologie und Pathologie*, Vol. II.

WINTZ, H., und RUMP, W. : " Messungen an Röntgenstrahlen. "

Fortschritte Röntgenstrahlen, Vol. 29, p. 671, 1922.

" Über die Tiefenwirkung der Röntgenstrahlen bei homogenen und inhomogenen Körpern. "

Fortschritte Röntgenstrahlen, Vol. 29, p. 580, 1922.

" Die physikalischen und technischen Grundlagen der Röntgentherapie. "

Lehrbuch der Strahlentherapie, Vol. IV, 1, 1929.

" Gynäkologische Röntgentherapie. " Part I : " Die physikalischen und technischen Grundlagen. "

Veit-Stoeckel : *Handbuch der Gynäkologie*, Vol. IV, 1, Hälfte, p. 196, 1930.

WHITTINGTON : " Some Experiments in X-Ray Protection. "

The Journal of Radiology, Vol. V, p. 347, 1924.

WITHERS, Sanford : " Coolidge-tube Protection. "

Radiology, June 1925, p. 502.

WÖLFFLIN, E. : " Über eine neue Schutzprothese zur Verhütung von Röntgenschädigungen des Auges. "

Fortschritte Röntgenstrahlen, Vol. 40, p. 943.

ZAKOVSKY, J. : " Röntgentechnik und Schädigungsprophylaxe. "
Sammelbericht Röntgenpraxis, I, p. 97.

ZOLLINGER, F. : " Die von der Schweizerischen Röntgengesellschaft vorgesehenen Schutzmassnahmen. "

Röntgenpraxis, Vol. II, p. 613, 1930.

Training of Physicians.

ALTSCHUL, W. : " Unterricht und Ausbildung in medizinischer Radiologie in der Tschechoslovakei. "

II. Internationaler Röntgenkongress, Stockholm, 1928.
Acta Radiologica, Supplementum IV, p. 103, 1930.

BARDEEN, Ch. R. : " The Use of Radiology in teaching Anatomy. "

Radiology, Vol. VII, p. 384.

BELOT, J. : " L'enseignement de la radiologie médicale en France. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 17.

BÉNARD-GUEDES, F. : " Der Unterricht in klinischer Röntgenologie in Portugal. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 108.

BLAINE, E. S. : " The Teaching of Roentgenology to Undergraduates. "

Radiology, Vol. VIII, p. 374.

CALM, A. W. : " Die Röntgenologie im Rahmen der Gesamtmedizin. "

Strahlentherapie, Vol. 25, p. 353, 1927.

CARMAN : " The Future of Radiology. "

Radiology, Vol. II, p. 41.

CARTY, John R. : " The Position of Roentgenology in the Undergraduate Medical Curriculum as seen by Recent Graduates. "

American Journal of Roentgenology, Vol. XXIII, p. 521.

Clark, J. . : " Undergraduate Instruction in Roentgenology. "
Radiology, Vol. VIII, p. 394.

Darling, B. C. : " Financing the Clinico-Pathological and X-Ray Laboratory in the Hospital, and also conserving the Professional and Economic Interests of its Medical Personnel. "
Radiology, Vol. VI, p. 127.

David, O. : " Irrwege moderner Röntgenologie, Zentralisation-Dezentralisation. "
Deutsche Med. Wochenschrift, p. 758, 1927.

Debicki, K. : " Unterricht in der Röntgenologie und medizinisches Studium. "
Polska Gazeta Lekarska, 1928, p. 32.
Internationale Radiotherapie, Vol. III, p. 141.

Dempster, J. H. : " The Teaching of Radiology to Undergraduates. "
Radiology, Vol. III, p. 325.

Forssell, G. : " Teaching in Medical Radiology. "
Acta Radiologica, Vol. IV, p. 638, 1925.
" Unterricht und Ausbildung in medizinischer Radiologie, mit besonderer Berücksichtigung der in Schweden gewonnenen Erfahrungen. "
Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 145, 1930.

Frank, L. : " The Relation of the Roentgenologist and his Work to the Surgeon. "
Radiology, Vol. VI, p. 187, 1926.

Gardner, R. A. : " The Organisation of the Teaching of Medical Radiology in Egypt. "
Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 112.

Gassul, R. : " Über Unterricht und Ausbildung in der Röntgenologie. "
Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 240.

Gauss, C. J. : " Zur Frage des radiologischen Unterrichts. "
Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 235.

Groedel : " Über Stand und Möglichkeiten der röntgenologischen Ausbildung der deutschen Ärzte und Studenten. "
Münchner Medizinische Wochenschrift, p. 310, 1925.

Grudzinski, Z. : " Contribution à la question d'enseignement de la radiologie médicale en Pologne. "
Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 233, 1930.

Haudek, M., Holzknecht, G., Kienböck, R., Weber, E. : International Association of University Lectures of Radiology.
The Journal of Radiology, Vol. VI, p. 347, 1925.

HEUSER, C. : " Radiology in the Argentine Republic. "
Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 116.

HEYERDAHL, S. A. : " The Instruction in Medical Radiology in Norway. "
Acta Radiologica, Vol. IV, p. 639, *Acta Radiologica*, Suppl. IV, p. 119, Stockholm, 1928.

HICKEY, P. M. : " The Teaching of Roentgenology in the University of Michigan. "
Radiology, Vol. VI, p. 125, 1926.

" Postgraduate Instruction in Roentgenology. "
Radiology, Vol. VIII, p. 379.

" The Teaching in Roentgenology in America. "
Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 34.

HOLITS, R. : " Unterricht der medizinischen Radiologie an den Universitäten in Ungarn. "
Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 123.

HOLTHUSEN, H. : " Die Stellung der Röntgenologie innerhalb der Medizin. "
Deutsche Medizinische Wochenschrift (Præmedicus), pp. 857, 939, 1029, 1929.

HOLZKNECHT, G. : Ärzteausbildung in der Röntgenologie. "
Müncher Medizinische Wochenschrift, p. 233, 1925.

" Special Training for Physicians in Roentgenology. "
Radiology, Vol. VI, p. 181.

" Über den Studentenunterricht in der medizinischen Anwendung der Röntgenstrahlen. "
Acta Radiologica, Suppl. IV, p. 5, 1930.

International Association of University Lecturers of Radiology.
Radiology, Vol. VI, p. 265.

KARPLUS : " Die Organisation des Unterrichts in der Röntgenologie und elektrophysikalischen Medizin in Frankreich. "
Deutsche Medizinische Wochenschrift, p. 759, 1927.

KNOX, R., and SCALES, Sh. : " The British Institute of Radiology : its Influence upon the Teaching of Radiology and Electrology. "
The American Journal of Roentgenology, Vol. XVI, p. 175, 1926.

" Leitsätze für die Anstellung selbständiger Röntgenärzte an Krankenanstalten. "
Fortschritte Röntgenstrahlen, Vol. 31, p. 146, 1923. (Zusammengestellt von der D.R.G. gelegentlich ihrer Tagung in München vom 15.-18. April 1923).

LINDSAY, G. A. : " Studies in the Physics of X-Rays for Students in Medicine. "
Radiology, Vol. VIII, p. 387.

MEYER, K. : " Communication sur l'enseignement théorique et pratique de la radiologie médicale. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 125, 1930.

MEYER, H. : Über den Unterricht in der Roentgenologie in Deutschland. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 48.

MELVILLE, St. : " Education in Radiology. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 41.

MURDOCH, J. : " L'enseignement de la radiologie médicale en Belgique. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 55.

" Nachweis über Erfahrung und Befähigung zur Bedienung der Röntgenapparatur (Gesundheitsamt New York.) "

Münchner Medizinische Wochenschrift, p. 807, 1926.

NAKAIDZUMI, M. : " Über Unterricht und Ausbildung in medizinischer Radiologie in Japan. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 128.

NEGRU, D. : " L'enseignement de la radiologie médicale en Roumanie. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 130.

NEMENOW, M. I. : " Über Ausbildung und Unterricht in der Radiologie in der U.S.S.R. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 61.

PANNER, H. J. : " The Instruction in Medical Radiology in Denmark. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 136.

PERUSSIA, F. : " La legge sugli specialisti. "

Radiologia med., XVI, 1929.

" L'enseignement de la radiologie médicale dans les universités italiennes. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 68.

PHYSIKER. " Berufung eines Physikers auf die Lehrkanzel für Röntgenologie (mit Bemerkungen Holzknechts). "

Fortschritte Röntgenstrahlen, Vol. 35, p. 841.

PLASENCIA, T. H. : " Un programme pour l'enseignement de la radiologie. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 242.

RATERA, J. : " Evolution historique et organisation de l'enseignement de la radiologie en Espagne. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 73.

RÉCHOU et MATHEY-CORNAT : " L'enseignement de l'électro-radiologie médicale à l'université de Bordeaux. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 237.

ROBINSOHN, I. : " Zur Methodik des Röntgenunterrichts und über die Erschliessung ausserklinischer Unterrichtsstätten. "

Röntgenpraxis, Vol. I, p. 934.

" Roentgenology in the Medical Curriculum. "

The American Journal of Roentgenology, Vol. XIII, p. 274, 1925.

SCHINZ, H. R. : " Unterricht und Ausbildung in medizinischer Radiologie an den schweizerischen Hochschulen. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 79.

" Zur Spezialarztfrage in medizinischer Radiologie. "

Röntgenpraxis, Vol. II, p. 1009, 1930.

SCHREUS, H. Th. : " Über die Stellung der Röntgenologie in der Medizin und Gesetzgebung und die Notwendigkeit eines Ausbaues besonderer Vertretung an den Universitäten. "

Strahlentherapie, Vol. 20, p. 432, 1925.

STENHUIS, D. J. : Über den Unterricht der medizinischen Radiologie in Holland. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 99, 1930.

TODD, W. : " The Rôle of Roentgenology in Medical Education. "

American Journal of Roentgenology, Vol. XVI, p. 355.

WEBER, E. : " Über den Stand des Studentenunterrichts in der medizinischen Röntgenologie in Lettland. "

Stockholm, 1928. *Acta Radiologica*, Suppl. IV, p. 142.

Training of Personnel.

American Registry of Radiological Technicians.

Radiology, Vol. II, p. 51.
American Journal of Roentgenology, Vol. XI, p. 367.

GÄRTNER : " Zur Frage der technischen Assistentinnen. "

Deutsche Medizinische Wochenschrift, p. 313, 1924. (Enthält den Erlass des Preussischen Ministers für Volkswohlfahrt vom 26. August 1921.)

GOLDSTEIN : " Die Ausbildung der technischen Assistentin an Medizinischen Instituten. "

Deutsche Medizinische Wochenschrift, p. 1481, 1927.

GROEDEL, F. M. : " Reformpläne zur Ausbildung der Röntgengehilfinnen. "

Fortschritte Röntgenstrahlen, Vol. 35, p. 1303, 1927.

" Zur Prüfungsordnung für technische Assistentinnen an medizinischen Instituten."

Deutsche Medizinische Wochenschrift, p. 463, 1922.

HILGERS, W. E., und WOHLFEIL : " Zur Frage der Ausbildung von technischen Assistentinnen an medizinischen Instituten." (Erfahrungen mit der psychotechnischen Eignungsprüfung.)

Deutsche Medizinische Wochenschrift, p. 535, 1928.

Hoffstaedt, E. : " Die Ausbildung der technischen Assistentinnen an Medizinischen Instituten."

Deutsche Medizinische Wochenschrift, p. 888, 1927.

Hoing, Margarete : " Case Management in Radiotherapy."

Radiology, Vol. XII, p. 249, 1929.

Holzknecht, G. : " Über die Stellung der Röntgenassistentin."

Röntgenpraxis, Vol. II, p. 481.

Josserand, P. : " Unzuträglichkeiten bei Ausübung der Röntgenologie durch Kurpfuscher."

Arch. d'électr. méd. No. 268.
Ref. *Fortschritte Röntgenstrahlen*, Vol. XIV, p. 226.

Kionka, J. : " Zur Ausbildung der technischen Assistentinnen."

Deutsche Medizinische Wochenschrift, p. 109, 1928.

Laquerrière, A. : " Bericht über die Ausübung der Elektrotherapie und der Röntgenologie durch nicht approbierte Personen."

Arch. d'électr. méd. XIV, No. 199.
Ref. *Fortschritte Röntgenstrahlen*, Vol. X, p. 381.

Laqueur, A. : " Zur Ausbildung des Hilfspersonals in der Physikalische Therapie."
Zschr. f. physikalische Therapie, Vol. 39, p. 155, 1930.

" Report of American Registry of Radiological Technicians."
Radiology, Vol. IV, p. 150.

" Technicians." *The Journal of Radiology*, Vol. IV, p. 280, 1923.

" A Course for Radiological Technicians." (Editorial.)

Radiology, Vol. V, p. 35.

A Letter from the American Registry of Radiological Technicians to those who contemplate offering Courses to Prospective Technicians.

Radiology, Vol. VI, p. 343.

" Roentgenoscopy by Technicians." (Editorial.)

American Journal of Roentgenology, Vol. XXI, p. 74.

Wolff, E. : " Zur Frage der technischen Assistentin."

Erwiderung auf den Aufsatz Prof. Gaertners in der *Deutschen Medizinischen Wochenschrift*, No. 10, p. 313, und *Zeitschrift für Röntgenologie*, No. 4, 1924. *Zeitschrift für Röntgenologie*, p. 125, 1924.

II. Protective Measures against Electric Accidents in X-Rays and Similar Establishments.

" Internationale Richtlinien für Röntgenstrahlen und Radiumschutz. "

Acta Radiologica, Suppl. III, Pars I, p. 66.
Fortschritte Röntgenstrahlen, Vol. 39, p. 343.

Austria.

" Sicherheitsvorschriften für elektrische Starkstromanlagen. " Herausgegeben vom Elektrotechnischen Verein in Wien. " Vorschriften für Röntgenanlagen. " Schönfeld, A. : " Schutzmassnahmen im Röntgenbetrieb. " (*De lege ferenda.*)

Wiener Medizinische Wochenschrift, Nos. 35, 36, 37, 38, 1929.

Czechoslovakia.

" Vorschriften des Čechoslowakischen Elektrotechnischen Verbandes für elektromedizinische Anlagen. " Teil XVIII des *Vorschriftenbuches ESC 1930.*

Denmark.

" Betaenkning fra det af Ministeriet for Sundhedsvaesen under 24. August 1927 nedsatte Røntgenudvalg. " Kobnhavn, Trykt hos G. H. Schultz a/s 1928.

England.

" Internationale Richtlinien. "

Germany.

" Vorschriften für den Hochspannungsschutz in medizinischen Röntgenanlagen. DIN Roent. 3. " Beuth Verlag, Berlin S.W.14, Dresdener Str. 97.

Fortschritte Röntgenstrahlen, Vol. 40, p. 542, 1929.

Greece.

Memorandum of the Greek Ministry of Public Health. (League of Nations, document C.H.827.)

Hungary.

Ratkoczi, Budapest : " On injuries in X-Ray Laboratories and Protective Measures. Proposals for Legislation providing for the Following Protective Measures. "

League of Nations, document C.H.775.

Spain.

Stadt Madrid. " Prescriptions of the Constitutional Council of Madrid : Chapter IX, (*a*). Medico-Electro-Radiological Installations. "

Sweden.

" Proposals from the Swedish X-Ray and Radium Protection Committee. " Second International Congress of Radiology. Stockholm July 23rd-27th, 1928.

Kungl. Boktryckeriet. P. A. Norstedt & Söner.

Switzerland.

" Richtlinien der Schweizerischen Röntgengesellschaft für die Erstellung und Führung von Röntgeneinrichtungen. "

Strahlentherapie, Vol. 31, p. 829.
Röntgenpraxis, II, p. 613, 1930.

Union of Soviet Socialist Republics.

Verfügung des " Volkskommissariats der Arbeit " der Räterepublik vom 22. Nov. 1924 No. 478/487 : " Sicherheitsmassregeln für elektrotechnische Anlagen mit starkem Strom von niedriger und hoher Spannung. "

Nachrichten des Volkskommissariats der Arbeit der Räterepublik 1924, No. 46.

* * *

ANGEBAUD : " Dispositif de protection pour haute tension dans les installations radiologiques. "

Journal de Radiologie et d'Electrologie, t. VII, p. 227.

BANGERT, K. : " Die Vorschriften für den Betrieb elektrischer Starkstromanlagen und ihre Anwendung in der Röntgentechnik. "

Zentralblatt Röntgenstrahlen, Radium und verwandte Gebiete, p. 3, 1919.

BEEKMANN : " Gewebsverbrennungen durch hohe Hitze. "

Klinische Wochenschrift, p. 743, 1923.

BORUTTAU, zit. nach BEHNKEN : *Handbuch der Physik*, Vol. 17, p. 197, 1926.

BOUWERS, A. : " Röntgenröhren mit vollständigem Hochspannungsschutz bis 200 kv. "

Strahlentherapie, Vol. 38, p. 157, 1930.

BREMON, J., y MASGRAU : " Los peligros del instrumental de alta tension para Rayos X. "

Revista de Diagnostoco y Tratamiento Fisicos, I, p. 139, 1925.

CONNOLLY, F. T. : " The Testing and Rating of Transformers for X-Ray Work. "

Brit. Journ. of Radiology (Journal of the Roentgen Society), Vol. 23, No. 92, p. 224, 1927.

ERBEN : " Spätwirkungen galvanischer Ströme. "

Medizinische Klinik, p. 426, 1923.

DELKESKAMP, G. : *Über Verletzungen durch den elektrischen Strom. Bruns Beiträge zur klinischen Chirurgie*, Vol. 141, p. 515, 1927.

FRITSCH, E. : " Die Beseitigung der Hochspannungsgefahr im Röntgenbetriebe durch den Securo. "

Fortschritte Röntgenstrahlen, Vol. 37, p. 309, 1928.
Ebenda, Vol. 40, Kongressheft, p. 110, 1929.
Strahlentherapie, Vol. 28, p. 810.

" Zur Frage des Hochspannungsschutzes an Röntgeneinrichtungen. "

Röntgenpraxis, Vol. II, p. 375, 1930.

GAUSS, C. J. : (Hochspannungsschutz.) *Lehrbuch der Strahlentherapie*, Vol. IV, 1, p. 374.

GROEDEL, F. M., und LOSSEN, H. : " Schutzmassregeln gegen elektrische Unfallschäden in modernen Röntgenbetrieben. "

Medizinische Klinik, p. 465, 1925.

HEMLER, W. F. : " High-Tension Electric Shocks in Roentgenologie Practice. "

American Journal of Roentgenology, Vol. IX, p. 365, 1922.

" Complete Insulation *versus* Grounding as Protection against High-Tension Electric Shocks."

American Journal of Roentgenology, Vol. XV, p. 49, 1926.

HOLSTEIN-RATHLOU : " De tekniske Forhold, der staar i Forbindelse med Ulykkestilfaeldet i Helsingör. "

Hosp.-Tid., 1928, p. 1.

JELLINEK : " Hautschädigungen durch Elektrizität. "

Wiener Klinische Wochenschrift, No. 9, 1923.

" Aufgaben und Ziele der Elektropathologie. "

Wiener Klinische Wochenschrift, p. 1181, 1929.

JONA, M., und ZAKOVSKY, J. : " Über Hochspannungsschutz an Röntgeneinrichtungen. "

Röntgenpraxis, Vol. I, p. 927, 1929.

KENNELLY, A. E. : " The Danger of Electric Shock from the Electrical Engineering Standpoint. "

Physic. Therapeut, Vol. 45, p. 16, 1927.

KLEMPERER : " Hochspannungsvoltmeter. "

Physikalische Zeitschrift, p. 673, 1927.

LEVY-DORN : " Die Tötung eines Ärztes und seiner Gehilfin durch den elektrischen Strom bei Vornahme einer Röntgenuntersuchung. "

Medizinische Klinik, p. 1762, 1924.

LEVY : " Kritische Bemerkungen über den Schutz gegen Hochspannungsgefahr für Arzt, Patient und Personal im Röntgenlaboratorium. "

Röntgenpraxis, Vol. I, p. 556, 1929.

MARAGLIANO : " L'impiego dell' oscilloscopio quele mezzo di misura della corrente de alta tensione. "

Radiologia Medica, 13, p. 205, 1926.

" Massregeln gegen die Hochspannungsgefahr in Röntgenzimmern. "
Ziekenhuis, p. 26, 1925.

MIEREMETT : " Hautveränderungen durch Einwirkung des elektrischen Stromes, ihre differentialdiagnostische Bedeutung und ihr histologisches Bild. "
Klinische Wochenschrift, p. 1362, 1923.

MUTSCHELLER, A. : " Physical Characteristics and Physiological Effects of High-Frequency Currents. "

Radiology, May 1927, p. 427.

NIEMANN : " Hochspannungsberührungsschutz. "

Fortschritte Röntgenstrahlen, Vol. 38, p. 1128, 1928.

NIXDORF und BRANDENBURG, zit. nach BEHNKEN : *Handbuch der Physik*, Vol. 17.

NÖLKE, W. : " Elektrischer Unfall durch einen Fusschalter. "

Röntgenpraxis, Vol. I, p. 512, 1929.

OTTO, W. : " Schutzeinrichtung von Hochspannungsschäden bei Berührung von hochspannungsführenden Teilen von Röntgenröhren. " (Zusatz zu DRP. 398, 541. 1927) DRP. 451, 815. 1927.

Zentralblatt für Radiologie, Vol. IV, p. 537.

PLAATS, B. J. VAN DER : " Massregeln gegen die Hochspannungsgefahr in Röntgenzimmern. "

II. Ziekenhuis, p. 46, 1928.
Fortschritte Röntgenstrahlen, Vol. 37, p. 270, 1928.

" Massregeln gegen die Hochspannungsgefahr in Röntgenzimmern. "

II. Ziekenhuis, p. 46, 1928.
Rheinisch-Westfälische Röntgengesellschaft 26. November 1927.
Sitzungsbericht : *Fortschritte Rntgenstrahlen*, Vol. 37, p. 270, 1928.

PANSDORF : " Starkstrom- und Hochspannungsschäden im Röntgenbetriebe. "

Röntgenpraxis, Vol. II, p. 359, 1930.

PFAHLER, G. E. : " A Protection Device for High-Voltage Therapy. "
The American Journal of Roentgenology, Vol. XIII, p. 291, 1925 (Zu Strahlenschutz).

PIETRUSKY, F. : " Zur Begutachtung elektrischer Unfälle. "
Monatsschrift für Unfallsheilkunde und Versicherungsmedizin, p. 121, 1927.

" Über den tödlichen elektrischen Unfall. "
Medizinische Klinik, p. 339, 1930.

POMETTA, D. : " Nothilfe bei elektrischen Unfällen. "
Schweizer Medizinische Wochenschrift, p. 82, 1930.
Zeitschrift für die gesamte physikalische Therapie, Vol. 39, p. 66, 1930.

SCHRIDDES : " Der elektrische Tod. "
Monatsschrift für Unfallheilkunde und Versicherungsmedizin, p. 275, 1925.

SOILAND, A. : " Further Remarks on Protective Measures with Special Reference to High Voltage. "
Radiology, Vol. II, p. 22.

SPIEGLER, G. : " Der akustische Milliamperezähler. "
Röntgenpraxis, Vol. I, p. 758, 1929.

Starke, H., und Schroeder, R. : " Ein direkt anzeigendes statisches Voltmeter für hohe Spannungen. "
Strahlentherapie, Vol. 29, p. 798, 1928.

Strassmann, G. : " Vier Todesfälle durch elektrischen Strom. "
Ärztliche Sachverständigenzeitung, No. 2, 1925.

Thibonneau : " Précautions à prendre contre les accidents dus aux chutes des trolleys. "
Journal de Radiologie, t. VII, p. 409.

Thoræus, R. : " How far can Ordinary Milli-Ammeters be used for reading Short-Time Currents ? "
Acta Radiologica, Vol. XI, p. 321, 1930.

Vulpius : " Seltene Folge eines Betriebsunfalles im Röntgenzimmer. "
Monatsschrift für Unfallheilkunde, p. 5, 1927.

Ziemke, E. : " Todesfälle durch den elektrischen Strom und ihre Beziehungen zum Unfall. "
Monatsschrift für Unfallheilkunde und Versicherungsmedizin, Nos. 5/6, 1923.

III. **Hygienic Measures in the Radiological Establishments.**

" Internationale Richtlinien für Röntgenstrahlen- und Radiumschutz. "
Acta Radiologica, Suppl. III, Pars 1, p. 66.
Fortschritte Röntgenstrahlen, Vol. 39, p. 343, 1929.

Austria.

Schönfeld, A. : " Schutzmassnahmen im Röntgenbetrieb. " (De lege ferenda.)
Wiener Medizinische Wochenschrift, Nos. 35, 36, 37 and 38, 1929.

England.

X-Ray and Radium Protection Committee. Third Revised Report (May 1927).
The British Journal of Radiology, Vol. 32, p. 330, 1927.

S. " Internationale Richtlinien. "

Germany.

" Vorschriften für den Strahlenschutz in medizinischen Röntgenanlagen. " (DIN-Röntgen-Normen.) Beuth-Verlag, Berlin, S.W. 14, Dresdenerstr. 97.
Vollständiger Wortlaut : *Fortschritte Röntgenstrahlen*, Vol. 41, p. 86, 1930.

Greece.

Memorandum of the Greek Ministry of Public Health.
League of Nations, document C.H.827.

Hungary.

Ratkoczi, Budapest : " On Injuries in X-Ray Laboratories and Protective Measures. Proposals for Legislation providing for the Following Protective Measures. "
League of Nations, document C.H.775.

Sweden.

" Proposals from the Swedish X-Ray and Radium Protection Committee. "
Kungl. Boktryckeriet. P. A. Norstdt & Söner.

Union of Soviet Socialist Republics.

" Verfügung des " Volkskommissariats der Arbeit " der Räterepublik vom 9. Sept. 1925, No. 233/389 betreffs des Arbeitsschutzes der in Röntgenkabinetten tätigen Arbeiter. "

Fortschritte Röntgenstrahlen, Vol. 35, p. 781, 1927.

* * *

Adam, A. : " Ultraviolettlicht und D-Vitaminforschung in ihrer Bedeutung für die Rachitis. "

Ergebnisse der medizinischen Strahlenforschung, Vol. IV, p. 109, 1930.

Andersen und Kohlmann : " Experimentelle Untersuchungen über die Ursachen des Röntgenkaters. "

Fortschritte Röntgenstrahlen, Vol. 30, Kongressheft, I and II, p. 148, 1922.

" Der Röntgenkater, seine Verhütung und seine Behandlung. "

Fortschritte der Therapie, Vol. IV, p. 75, 1928.

Blumer, L.: " Verhütung der Strahlenschädigungen vom Standpunkt des Gynäkologen."
Schweizer Medizinische Wochenschrift, p. 606, 1927.
Zentralblatt Radiologie, Vol. III, p. 777.

Bouchacourt, L. : " Sur la protection des radiologistes pendant les examens radioscopiques. "

Journal de Radiologie, t. 14, p. 487, 1930.

Braun, Reichsarbeitsminister. Berlin, 6. August 1925. " Die Richtlinien über gewerbliche Berufskrankheiten. "

Klinische Wochenschrift, p. 1750, 1925.

Bureau international du Travail : Radiologues (Pathologie professionnelle et hygiène). D'après un rapport original du professeur F. Perussia (Milan) revisé par le Comité de correspondance d'hygiène industrielle du Bureau international du Travail.
Hygiène du Travail, No. 131.

Bucky, G. : " Die Diathermie-Behandlung des Röntgenkaters ".
Fortschritte Röntgenstrahlen, Vol. 30, Kongressheft, I and II, p. 151, 1922.

Burgheim, F. : " Die Bedeutung des Cholesterins für das Zustandekommen und die Verhütung des ' Röntgenkaters '. "
Deutsche Medizinische Wochenschrift, p. 1858, 1927.

" Neue Untersuchungen zur Pathogenese und Therapie des Röntgenkaters. "
Strahlentherapie, Vol. 27, p. 297, 1927.

Czepa und Högler : " Zur Pathogenese des Röntgen- und Radiumkaters. "
Klinische Wochenschrift, p. 2341, 1923.

DADLEZ (Ozonisierende Wirkung der Quecksilberdampflampe). Comptes rendus 185, p. 89, 1927.

Zit. nach Adam. *Ergebnisse der medizinischen Strahlenforschung*, Vol. IV, p. 109.

DAVID, O., und HIRSCH, M. : " Über die Ventilation von Röntgeninstituten (mit einer Übersichtsskizze). "

Acta Radiologica, Vol. IX, p. 305, 1928.

DÖDERLEIN, A. : " Strahlenbehandlung und Nachkommenschaft. "
Deutsche Medizinische Wochenschrift, p. 1997, 1928.

DYES, Otto : " Die Dunkelkammer und ihre zweckmässige Einrichtung. "
Fortschritte Röntgenstrahlen, Vol. 42, p. 387, 1930.

FISCHER, Eugen : " Strahlenbehandlung und Nachkommenschaft. "
Deutsche Medizinische Wochenschrift, p. 89, 1929.

FLASKAMP, W. : " Röntgenschädigungen, ihre zivil- und strafrechtlichen Folgen. "
Klinische Wochenschrift, No. 22, 1922.

" Röntgenschädigungen als Unfälle und Gewerbekrankheiten. "
Fortschritte Röntgenstrahlen, Vol. 32, p. 641, 1924.

" Über Röntgenschäden und Schäden durch radioaktive Substanzen. "

12. Sonderband der Strahlentherapie. Verlag Urban und Schwarzenberg, Berlin-Wien, 1930.

FOVEAU DE COURMELLES : " Radioanaphylaxie. "
Arch. d'Electr. méd. et de Physiothérapie, No. 482, p. 327, 1922.
Fortschritte Röntgenstrahlen, Vol. 31, p. 129, 1923.

FRIESLEBEN, M. : " Berufliche Röntgenschädigungen und ihre Verhütung. "
Deutsche Medizinische Wochenschrift, p. 464, 1929.

" Röntgenschädigungen beim Hilfspersonal. "

Deutsche Medizinische Wochenschrift, p. 1680, 1929.

FRIK, K., und LEVY-DORN, Max : " Die beim Arbeiten mit Röntgenstrahlen auftretenden Gefahren und ihre Verhütung. "

Deutsche Zeitschrift für öffentliche Gesundheitspflege, p. 147, 1927.
Zentralblatt für Radiologie, Vol. IV, p. 358.

GUTHMANN : " Schädigungen an Bestrahlten und Bestrahlern durch die im Röntgenzimmer entstehenden Gase. " Erlangen, Dissertation, 1919.

Sitzungsberichte der Physikalisch-Medizinischen Sozietät in Erlangen. Vols. 50, 51 (1918-19).

" Über den Gehalt der Röntgenzimmerluft an Ozon und salpetriger Säure und über die Ursache der Röntgengasvergiftung (Ozonwirkung). "

Strahlentherapie, Vol. 12, p. 262.

" Nochmals zur Frage der Gasvergiftung im Röntgenzimmer. Erwiderung an Herrn Dr. Lönne. "

Münchner Medizinische Wochenschrift, p. 89, 1922.

Hahn, K. : " Röntgenstrahlenschädigungen der Haut, ihre Prophylaxe und Therapie mit Raderma. "

Medizinische Klinik, No. 44, 1930.

Hoffmann, F. L. : " Radiumnekrose. "

Journ. Amer. Med. Assoc. 85/13, p. 961.
Ref. *Fortschritte Röntgenstrahlen*, Vol. 34, p. 208, 1925.

Lacassagne, A. : " Eine neue Berufskrankheit bei der Hantierung mit radioaktiven Körpern. "

Paris méd., p. 132, 1926.
Ref. *Fortschritte Röntgenstrahlen*, Vol. 34, p. 822, 1926.

" Anémie pernicieuse et leucémie myéloïde mortelles provoquées par la Manipulation de substances radioactives. " (En collaboration avec Emile Weil.)

Bulletin de l'Académie de Médecine, 3rd Series, Vol. XCIII, p. 237.

Lignac et Devois : " A propos de la pathogénie du mal des irradiations pénétrantes. "

La Presse médicale, No. 27, p. 292 (April 2nd, 1924)

Loeffler, L. : " Röntgenschädigungen der männlichen Keimzelle und Nachkommenschaft. Ergebnisse einer Umfrage bei Röntgenärzten und Technikern. "

Strahlentherapie, Vol. 34, p. 735.

Loenne : " Zur Kritik der Ozonbestimmung. Ein Beitrag zur Frage der Gasvergiftung im Röntgenzimmer. "

Münchner Medizinische Wochenschrift, p. 1519, 1921.

Lundquist, A. : " Über die Einrichtung der Dunkelkammer an Röntgenabteilungen. "

Acta Radiologica, Vol. IX, p. 65, 1928.

Mahnert und Zacherl : " Die Behandlung des Röntgenkaters mit hypertonischen Lösungen. Zugleich ein Beitrag zur Frage ihrer Wirkungen. "

Wiener klinische Wochenschrift, No. 7, 1923.

Mallet et Coliez : " Influence de l'ozone dans le mal des irradiations. "

Journal de Radiologie et d'Electrologie, 1922, No. 6.

Martland, H. S., Coulon, P., und Knef, J. P. : " Einige unbekannte Gefahren bei dem Gebrauch und der Hantierung mit radioaktiven Substanzen, mit besonderer Beziehung auf die Speicherung unlöslicher Radium- und Mesothoriumprodukte im reticulo-endothelialen System. "

Journ. Amer. Med. Assoc. 1925/85, p. 1769.
Fortschritte Röntgenstrahlen, Vol. 34, p. 424.

Melville, St. : " Radiography as it affects the Assurability of Operators. "

The Lancet, February 12th, 1927.

MEMMESHEIMER : " Ein Beitrag zur Frage des Röntgenkaters. "
Strahlentherapie, Vol. 16, p. 741, 1924.

MURPHY, D. P. : " Ovarian Irradiation; its Effect on the Health of Subsequent Children. Review of Literature, experimental and clinical, with a Report of three hundred and twenty Human Pregnancies. "
Surg., Gynec., Obstetr., Vol. 47, p. 201, 1928.
Zentralblatt Radiologie, Vol. VI, p. 458.

" Ovarian Irradiation and the Health of the Subsequent Child. A Review of more than two hundred previously Unreported Pregnancies in Women subjected to Pelvic Irradiation. "
Surg., Gynec., Obstetr., Vol. 48, p. 766, 1929.
Zentralblatt Radiologie, Vol. VII, p. 527.

NAUJOKS, H. : " Die Entwicklung der Kinder, die nach temporärer Strahlensterilität der Mutter geboren wurden. "
Strahlentherapie, Vol. 37, Chap. 3.

" Fertilität und Nachkommenschaft früherer Röntgenassistentinnen. " (Ein Beitrag zur sog. " Keimschädigung ".)
Strahlentherapie, Vol. 32, p. 613.

NEUDA, REDLICH, SIELMANN : " Zur Pathogenese des sog. Röntgenkaters. "
Klinische Wochenschrift, No. 28, p. 1306, 1923.

NEUDA : " Patogénesis del llamado ' Kater ' roentgenologica. "
Revista de Radiologia, Year 2, p. 4, 1924.

NÜRNBERGER, L. : " Die tierexperimentellen Grundlagen zur Frage der Spätschädigung durch Röntgenstrahlen. "
Strahlentherapie, Vol. 37 (Festschrift für Döderlein).

PERUSSIA : " Berufliche Pathologie und Hygiene des Röntgenologen ".
See under : Bureau international du Travail.

REINBERG, S., und KUPRITZ, E. : " Gewerbliche Schädigung bei der Herstellung von Röntgenröhren in der (Leningrader) Elektrovakuumanstalt. "
Gigiena truda, No. 7/8, pp. 59/66.
Internationale Radiotherapie, Vol. II, p. 59.

REUSCH, W. : " Gasvergiftung im Röntgenzimmer und ihre Verhütung. "
Münchner Medizinische Wochenschrift, p. 445, 1917.

Röntgenkater (Acidosis) : *Radiology*, Vol. II, p. 160, 1924.

ROSENZWEIG, B. K. : " Berufliche Erkrankungen der Röntgenologen und ihre Prophylaxe. "
Fortschritte Röntgenstrahlen, Vol. 36, p. 778, 1927.

RUSSIE. — " La Journée des Médecins Radiologistes. "
Journal de Radiologie, t. X, p. 19.

Schechtmann, J. : " Die Luftionisation in Röntgenräumen. "
Fortschritte Röntgenstrahlen, Vol. 42, p. 639.

Schmitt, W. " Über die spätere Entwicklung der Kinder vorbestrahlter Frauen. "
Strahlentherapie, Vol. 30, p. 24, 1928.
Monatsschrift für Geburtshilfe und Gynäkologie, Vol. 80, p. 157. Aussprache, p. 195, 1928.

Schmitz, H. : " The Treatment of Primary and Latent Injuries of the Skin from Radium and X-Rays. "
Radiology, Vol. I, p. 34, 1923.
" The Clinical Significance and Treatment of Radiation Sickness. "
Radiology, Vol. II, p. 137, 1924.

Schönfeld, A. : " Schutzmassnahmen im Röntgenbetrieb. "
Wiener Medizinische Wochenschrift, No. 35, 36, 37 and 38, 1929.

Sielmann : " Untersuchungen über den Einfluss der Röntgenstrahlen auf den Kochsalzstoffwechsel und seine Beziehungen zur Therapie des ' Röntgenkaters '. "
Strahlentherapie, Vol. 15, p. 458, 1923.

Solomon, I. : *Précis de radiothérapie profonde.*
Masson & Cie, Editeurs, Paris, 1926.

Uhlmann, H. : " Über die Möglichkeit der Vremeidung von Strahlenschäden der Haut. "
Strahlentherapie, Vol. 38, 1930.

Unterberger : " Röntgenschädigung der Frucht durch wiederholte Durchleuchtungen während der Schwangerschaft. "
Zentralblatt für Gynäkologie, p. 44, 1929.

Verhandlungen der Deutschen Röntgengesellschaft, Vol. 17*a*. " Ovarialbestrahlung und Nachkommenschaft. " Aussprache.
Fortschritte Röntgenstrahlen, Vol. 35, Kongressheft, pp. 30 *et seq.*, 1926 (Naturforschertagg, Düsseldorf).

Verhandlungen der Deutschen Gesellschaft für Gynäkologie, Leipzig 1929. Ausssprache über die Frage der Keimschädigung.
Archiv. f. Gynäkologie, Vol. 137, p. 974.

Verhandlungen der Bayerischen Gesellschaft für Geburtshilfe und Frauenheilkunde. " Zur Frage der Keimschädigung nach Röntgenbestrahlung der Ovarien. " Sitzungsberichte.
Monatsschrift für Geburtshilfe und Frauenheilkunde, Vol. 56, p. 92 (1921) ; Vol. 67, p. 228 (1924) ; Vol. 71, p. 204 (1925) ; Vol. 76, p. 349 (1925) ; Vol. 79, p. 122 (1927) ; Vol. 80, p. 179 (1927) ; Vol. 88, p. 111 (1931).

Verhandlungen der Bayerischen Gesellschaft für Geburtshilfe und Frauenheilkunde. Sitzung vom 27. Februar 1927 zu München. " Richtlinien zur Unterbrechung der Schwangerschaft bei Verdacht auf Keimschädigung nach Bestrahlung der Frucht in utero. "
Monatsschrift für Geburtshilfe und Gynäkologie, Vol. 79, p. 141. 1927.

Vorschriften für das Verhalten nach der Bestrahlung und für die Behandlung der bestrahlten Hautstellen.

Röntgeninstitut der Universitäts-Frauenklinik Erlangen (Direktor : Professor Dr. H. Wintz).

WARREN and WHIPPLE : " Roentgen-Ray Intoxication. "

Journal of Experimental Medicine. Vol. 38, pp. 713, 725, 731, 741, 1923.

WEBER, E. : " Schädigungen des Kranken und des Personals im Röntgenbetriebe und deren Prophylaxe. Hygiene des Röntgenbetriebs. "

Fortschritte Röntgenstrahlen, Vol. 34, p. 728, 1926.

WELSCH, K. : " Die Salbenbehandlung der bestrahlten Haut. "

Münchner Medizinische Wochenschrift, p. 1489, 1930.

WINTZ, H. : " Die Gasvergiftung im Röntgenzimmer. "

Münchner Medizinische Wochenschrift, p. 297, 1918.

" Röntgenschädigungen in der Tiefentherapie. " (Kombinationsschäden !)

Fortschritte Röntgenstrahlen, Vol. 30, p. 133, des Kongressheftes.

" Injuries from Roentgen-Rays in Deep Therapy. "

American Journal of Radiology, Vol. X, p. 140, 1923.

" Die Vor- und Nachbehandlung nach Röntgenbestrahlung. "

Therapie der Gegenwart, Juni 1923.

" Fore-care and After-care. "

Radiology, Vol. II, 1924.

" Die Mitarbeit des praktischen Ärztes bei der Röntgentherapie. "

Deutsche Medizinische Wochenschrift, p. 700, 1927.

" Strahlenschäden an Hoden, Eierstock und Frucht. "

Monatsschrift für Geburtshilfe und Gynäkologie, Vol. 78, p. 428, 1928.

" Die Methodik der Röntgentherapie " in *Handbuch der gesamten Strahlenheilkunde, Biologie, Pathologie und Therapie* herausgegeben von Lazarus. Verlag J. F. Bergmann, München, 1928.

WINTZ, H., und FLASKAMP, W.: " Zur Frage der Schädigung der Nachkommenschaft durch Röntgenstrahlen. " Naturforschertagung, Düsseldorf, 1926.

Fortschritte Röntgenstrahlen, Vol. 35, Kongressheft, p. 42.

WULLYAMOZ, Lausanne : " Un cas d'aspermatozoidie roentgénienne guéri par le port pendant huit mois d'un tablier protecteur invisible sous les vêtements. "

Arch. d'électricité méd., p. 278, 25 janvier 1910.
Ref. *Journal de Radiologie,* t. IV, p. 63, 1910.
Fortschritte Röntgenstrahlen, Vol. XV, p. 54.

ZWEIFEL, E. : " Kein Röntgenkater mehr ! "
Strahlentherapie, Vol. 18, p. 875, 1924.
Hierzu : *Czepa*, Vol. 19, p. 601 und Schwartz, p. 606.

Materialiensammlung der Unfälle und Schäden in Röntgenbetrieben. Herausgegeben von F. M. Groedel, G. Liniger und H. Lossen.

Fortschritte Röntgenstrahlen, Ergänzungsband 36, fasc. 1 (first fasc.), 1925. Ergänzungsband 33 (second fasc.), 1927.

Materialiensammlung von Unfällen und Schäden in Schweizerischen Röntgenbetrieben.

Herausgegeben von H. R. Schinz und F. Zollinger.
Röntgenpraxis, II, pp. 385, 433, 505, 546, 613, 1930.

IV. Safe-Guarding of Storage of X-Ray Films.

Germany.

" Denkschrift des preussischen Ministeriums für Volkswohlfahrt vom 2. März 1929, über die Gefahren der in den Krankenhäusern verwendeten Röntgen-usw.-Filme aus Zelluloid. "

Mitteilungen, in Röntgenpraxis, Vol. I, p. 472, 1929.

Bayern. — " Sammlung von feuerpolizeilichen Vorschriften in Bayern ", herausgegeben von O. Hofmiller.
München 1929, Schweitzer Verlag. Vorschriften vom 9. März 1912 in der Fassung vom 19. Juni 1926.

Frankfurt. — Örtliche Regelung der Filmaufbewahrung im Frankfurter Bezirk. "
Mitteilungen, in Röntgenpraxis, Vol. II, p. 273, 1930.

Normenstelle der Deutschen Röntgengesellschaft " Arbeitsgruppe IX " Filmkonservierung. Vorschriften für die Handhabung und Lagerung von Röntgenfilmen in medizinischen Betrieben. (Din-Röntgen-Normen.) Vorschlag 1. Einspruchsfrist bis 1. September 1930.

Fortschritte Röntgenstrahlen, Vol. 42, p. 130, 1930. (Vollständiger Wortlaut.)
Schlussentwurf: Din Rönt. 3; Beuth Verlag, G.m.b.H. Berlin, S. 14.

Normenstelle der Deutschen Röntgengesellschaft, Arbeitsgruppe IX " Filmkonservierung " : Vorschriften für die Handhabung und Lagerung von Röntgenfilmen in medizinischen Betrieben. (Din Roent 3).

Fortschritte Röntgenstrahlen, Vol. 43, p. 113, 1931.
Strahlentherapie, Vol. 40, p. 392. (Endgültige Fassung).

Normenstelle der Deutschen Röntgengesellschaft, " Arbeitsgruppe IX ", Bemerkungen zu dem Artikel des Herrn Dr. Wertheimer (Über Röntgenfilmaufbewahrung).

Röntgenpraxis, Vol. II, p. 957.
Röntgenpraxis, Vol. II, pp. 958 and 960.
Fortschritte Röntgenstrahlen, Vol. 42, pp. 669 *et seq.*

England.

" Handling and Storage of X-Ray Films. " Recommendation of the X-Ray and Radium Protection Committee.

Brit. Medical Journal, No. 3593, p. 923.
Zentralblatt Radiologie, Vol. VIII, p. 211.

United States of America.

Proceedings of the Board of the Chemical Warfare Service, appointed for the purpose of investigating conditions incident to the disaster of the Cleveland Hospital Clinic, Cleveland, Ohio, on May 15th, 1929, Edgewood Arsenal, Maryland l. T., Walter C. Baker, C.W.S., Commanding.
Summary in " Report on the Recent Fire at the University of California Hospital. ", by Howard E. Ruggles.

American Journal of Roentgenology, Vol. XXIII, p. 84, 1930.

Report of the Committee on Safety and Standards.

" Regulations for the Storage and Handling of Photographic and X-Ray Nitro-Cellulose Films. "

American Journal of Roentgenology and Radium Therapy, Vol. XXIII, p. 81.

* * *

Balasz, G. : " Über die beim Brennen der Röntgenfilme entstehenden Gasvergiftungen. "

Magy. Röntgen-Közl., p. 263, 1929.
Zentralblatt Radiologie, Vol. VIII, p. 757.

Barke : " Röntgenfilme in Krankenhäusern, ihre Gefahren und deren Anwendung. "

Zeitschrift für Krankenhauswesen, p. 265, 1930.
Zentralblatt Radiologie, Vol. IX, p. 259.

Behn : " Einiges zur Filmfrage. "

Röntgenpraxis, Vol. I, p. 843, 1929.

Braun-Solingen : " Neue Wege zur Verhütung der Gas- und Feuersgefahr beim Aufbewahren von Röntgenfilmen. "

Röntgenpraxis, Vol. II, p. 84, 1930.

"Über Aufbewahrung von Röntgenfilmen." Naturforschertagung, Königsberg, 1930.

Röntgenpraxis, Vol. II, p. 953, 1930.

Brown, C. R. : " Safeguarding the Storage of Photographic, Motion-Picture and X-Ray Films. "

Radiology, Vol. XIV, p. 454, 1930.

Disaster at the Cleveland Hospital Clinic.

Government Printing Office, Washington, 1929.

Effenberger : " Die Lagerung von Röntgenfilmen in Krankenhäusern. "

Feuerschutz, Zeitschrift des Reichsvereins Deutscher Feuerwehringenieure, Berlin, April 1930.

Feilitzen, von : *Brandskydd, Svenska Brandskyddsföreningens tidskrift*, Okt. 1929.

Foley, M. O. : " Cleveland Disaster spurs Inquiry into Hospital Film Storage Methods. "
Hospital Management, Vol. XXVII, No. 6, 1929.

Giebmanns : " Wirksame Bekämpfung von Filmbränden. "
Strahlentherapie, Vol. 38, p. 196, 1930.

Glocker, R. : " Die Filmbrandgefahr und die Massnahmen zu ihrer Verhütung. "
Fortschritte Röntgenstrahlen, Vol. 41, p. 53.

Haenisch, F. : " Über die Aufbewahrung des Filmarchivs. "
Röntgenpraxis, Vol. II, p. 273, 1930.

" Filmkonservierung. " Referat gehalten auf der Tagung der Deutschen Naturforscher und Ärzte. September 1930, Königsberg in Pr.
Röntgenpraxis, Vol. II, p. 952, 1930.

Herrnkind, O. P. : " Die Feuergefährlichkeit der Röntgenfilme. "
Röntgenpraxis, Vol. I, p. 649, 1929.

Hobbs, R. D. : " Methoden der Aufbewahrung von Röntgenfilmen, um der Feuersgefahr vorzubeugen. "
Journal of the American Medical Association, Vol. 92, p. 1763, 1929. Ref. *Fortschritte Röntgenstr.*, Vol. 40, fasc. 2.

Aus der röntgentechnischen Abteilung der I. G. Farben Industrie A.-G. (Leiter : Dr. Limpach) : " Über die Feuergefährlichkeit von Röntgenfilms. " (Bemerkungen zu dem Aufsatz von Prof. Dr. Walter Straub.)
Münchner Medizinische Wochenschrift 1929, No. 25.
Münchner Medizinische Wochenschrift, p. 1565, 1929.

Janker-Bonn : " Zur Möglichkeit der Selbstentzündung von Röntgenfilmen. "
Röntgenpraxis, Vol. I, p. 378.

Kaiser : " Aufbewahrung von Röntgenfilmen in Schränken aus Hartholz. "
Feuerschutz, Zeitschrift des Reichsvereins Deutscher Feuerwehringenieure, Berlin, Februar 1930, No. 2, p. 22.

Klassen : " Der Röntgenfilmbrand im Krankenhaus in Cleveland. "
Feuerschutz, p. 138, 1929.

" Filmlagerungen in Krankenanstalten und Krankenkassengebäuden. "
Feuerschutz, p. 181, 1928.

Knutsson, F. " Über die Feuergefährlichkeit des Röntgenfilms. "
Acta Radiologica, Vol. X, p. 566, 1929.

Krause, P. : " Sicherung gegen Explosionsgefahr von Röntgenfilmen. "
Fortschritte Röntgenstrahlen, Vol. 41, p. 477, 1930.

LEHMANN : " Sitzungsbericht der Normenstelle der Deutschen Röntgengesellschaft Arbeitsgruppe IX " Filmkonservierung. "
Fortschritte Röntgenstrahlen, Vol. 41, p. 989, 1930.

LIMPACH : " Massenvergiftung durch verbrennende Röntgenfilms. "
Münchner Medizinische Wochenschrift, p. 1565, 1929.

LOWRY : " An Accessory Protective Measure in Film Storage. "
Radiology, Vol. 14, p. 157, 1930.

NICHOLS, B. H. : " The Clinical Effects of the Inhalation of Nitrogen Dioxide. "
American Journal of Roentgenology, Vol. XXIII, p. 516, 1930.

NIEHAUS, H. : " Sickerheitsmassnahmen bei der Lagerung von Röntgenfilmen. "
Röntgenpraxis, Vol. II, p. 705, 1930.

OSTERMANN : " Die Feuergefahr der Röntgenfilme in Krankenanstalten. "
Medizinische Welt, p. 797, 1929.

ROCCHI, G. : " Sulla Inflammabilità delle pellicole radiografiche. "
Radiologia medica, Vol. XVI, 1929.

RÖCKER : " Über Vorbeugungsmassnahmen bei Filmbränden in Krankenhäusern. "
Fortschritte Röntgenstrahlen, Vol. 41, p. 474, 1930.

RUGGLES, H. E. : " Report on the Recent Fire at the University of California Hospital. "
American Journal of Roentgenology, Vol. XXIII, p. 83, 1930.

SANDERS, G. B. : " Roof Vault provides Safe Storage for X-Ray Films. "
Modern Hosp., Vol. XXIII, p. 53, 1929.

SZYNDANYI, S. : " Feuersicherheitsmassregeln bei der Einlagerung des Filmmaterials der Röntgenlaboratorien. "
Magy. Röntgen-Közl. Vol. 3, p. 261, 1929.
Zentralblatt für Radiologie, Vol. VIII, p. 757.

SCHÖNFELD, A. : " Röntgenfilm und Feuerschutz. "
Wiener Klinische Wochenschrift, p. 1231, 1928.

SCHULTE, G. : " Die im Knappschaftskrankenhaus Recklinghausen bestehenden Schutzeinrichtungen für die Aufbewahrung von Röntgenfilmen. "
Fortschritte Röntgenstrahlen, Vol. 41, p. 476, 1930.

STRAUB, W. : " Massenvergiftung durch verbrennende Röntgenfilme. "
Münchner Medizinische Wochenschrift, p. 1049, 1929.

Verhandlungen der Deutschen Röntgengesellschaft (Tagung der Gesellschaft Deutscher Naturforscher und Ärzte. 7.-11. September 1930 in Königsberg Pr.).
Referate über Filmkonservierung (Haenisch, Wagner, Pleus).
Fortschritte Röntgenstrahlen, Vol. 42, Kongressheft, p. 17.

Verhandlungen der Rheinisch-Westfälischen Röntgengesellschaft, 2. November 1929 zu Essen. " Über Explosionsgefahr der Röntgenfilme und ihre Vermeidung. "

Fortschritte Röntgenstrahlen, Vol. 41, p. 474, 1930.

Wagner und Pleus : Erläuterungen zu den Vorschriften DIN Roent für die Handhabung und Lagerung von Röntgenfilmen in medizinische Betrieben.

Fortschritte Röntgenstrahlen, Vol. 43, p. 236, 1931.

Wagner : " Röntgenfilme in Krankenhäusern, ihre Gefahren und deren Abwendung. "

Feuerschutz, Zeitschrift des Reichsvereins Deutscher Feuerschutzingenieure, Berlin, 1930, p. 29. (Bericht von D. Backe, Berlin, in *Röntgenpraxis* 11/9, p. 431, 1930.)

Watters, R. A., and Piersall, C. E. : " X-Ray Films ; Methods of Filing to prevent Possibility of Fire. "

Journal American Medical Association, Vol. XCII, p. 1763, 1929.

Wertheimer, A. : " Über die Röntgenfilmaufbewahrung. "

Strahlentherapie, Vol. 36, p. 573, 1930.

" Über die Röntgenfilmaufbewahrung. "

Röntgenpraxis, Vol. II, p. 957.

" Bemerkung zur Erwiderung der Filmkonservierungskommission. "

Röntgenpraxis, Vol. II, p. 959, 1930.

Fortschritte Röntgenstrahlen, Vol. 42, pp. 669 *et seq.*

Hospital and Institution Fires.

National Fire Protection Association. International. Boston, Mass.

Addendum.

I. Protection against Dangers caused by Radiation.

Baensch, W. : " Besserer Strahlenschutz für die Hände des Röntgenologen. "
Röntgenpraxis, Vol. III, chap. 6, p. 286, 1931.

Belot, J. : " Paravent protecteur du docteur J. Belot. "
Bull. Soc. radiol. méd. France, XVIII, pp. 120-124.
Ref. Zentralblatt für Radiologie. IX, 15.

Habs, H. : " Die Gefahr des Palpierens mit der ungeschützten Hand. "
Fortschritte Röntgenstrahlen, Vol. 42, p. 779.

La Roche, O. : " La protection contre les rayons X et l'électrocution. " (Film de la maison Gaiffe, Gallot et Pilon.)
Bull. Soc. radiol. méd. France, XVIII, p. 164.
Zentralblatt Radiologie, Vol. IX, p. 16.

IV. Protective Measures against the Danger of X-Rays Film Fires.

Normenstelle der Deutschen Röntgengesellschaft, Arbeitsgruppe IX, " Filmkonservierung " : " Vorschriften für die Handhabung und Lagerung von Röntgenfilmen in medizinischen Betrieben. " (DIN ROENT 3.)
Fortschritte Röntgenstrahlen, Vol. 43, p. 113, 1931.
Strahlentherapie, Vol. 40, p. 392. (Rédaction définitive.)

Wagner und Pleus : " Erläuterungen zu den Vorschriften DIN ROENT 3 für die Handhabung und Lagerung von Röntgenfilmen in medizinischen Betrieben. "
Fortschritte Röntgenstrahlen, Vol. 43, p. 236, 1931.

Verhandlungen der Deutschen Röntgengesellschaft (Tagung der Gesellschaft Deutscher Naturforscher und Ärzte, 7.-11. Sept. 1930 in Königsberg (Pr.)).
" Referate über Filmkonservierung " (Haenisch, Wagner, Pleus).
Fortschritte Röntgenstrahlen, Vol. 42, p. 17.

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L'ORGANISATION SANITAIRE DES PAYS-BAS. Vingt-neuf conférences données à l'occasion du voyage d'études organisé par l'Organisation d'hygiène de la Société des Nations, avril-mai 1924. (French text only). (C.H./E.P.S. 48)	4/—	$1.00
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