A PICTORIAL SYSTEM OF INSTRUCTION

X-RAY DIAGNOSIS

X-RAY THERAPY

PHOTO-THERAPY

HOT-AIR THERAPY

VIBRATION THERAPY

HIGH-FREQUENCY ELECTRIC CURRENTS

BY
S. H. MONELL

E. R. PELTON
NEW YORK

45c-

A System of Instruction in X-Ray Methods and
Medical Uses of Light, Hot-Air, Vibration
and High-Frequency Currents

THE author is one of the most illustrious teachers of electro-therapeutics in America.

—Medical Sentinel.

FROM such a practical observer and teacher as Dr. Monell one must accept his results as from one qualified to dictate.

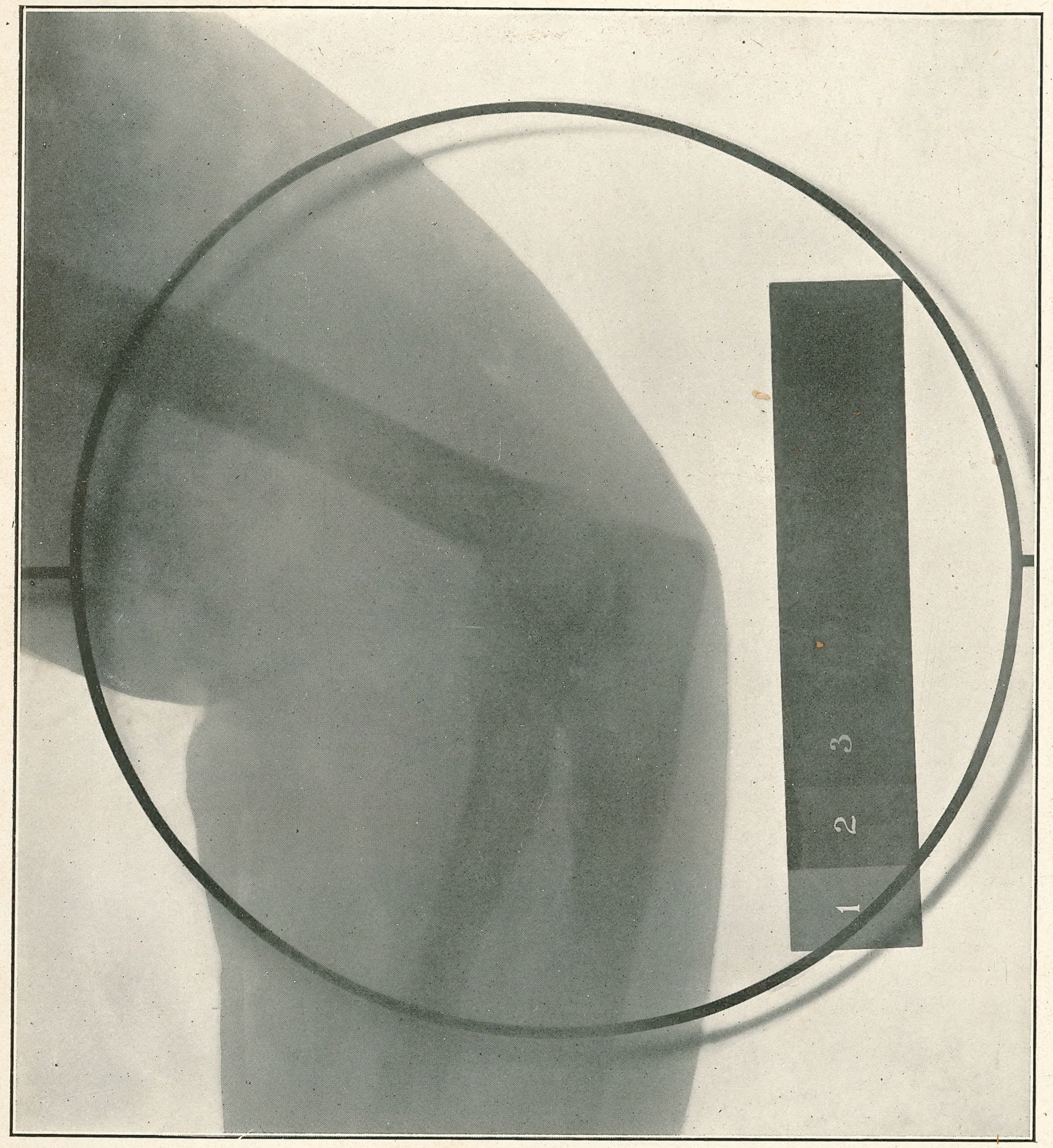
—Canada Medical Record.

DR. MONELL is regarded as one of the foremost thinkers of the medical world, and in electro-therapeutics has done more for Static electricity than any other living man. His voluminous writings have made for him a living history. His books on the uses of electric currents in X-ray work and in electro-therapeutics have had an enormous sale. As author, teacher, scholar, he is at the top.

—The American X-Ray Journal.

WITHIN the past few years there has been a remarkable increase in the use of the Static machine, and one of the foremost in advocating and popularizing its use in the profession has been Dr. S. H. Monell. He has also forced the recognition of the Static machine as a means for producing the X-ray, and that against determined opposition. A visit to his office gives no indication of ostentation or exaggeration, but convinces one that he is moderate in his claims, and has accomplished what he has by hard work and unremitting attention.

—Cleveland Medical Gazette.



The first "Medico-Legal' Radiograph ever published, Proving Technic of Exposure by Evidence Imprinted in the Negative when it was made.

DESCRIPTION OF INSTRUCTION PLATE PROVING TECHNIC OF EXPOSURE

By Evidence Imprinted in the Negative when it was made.

The 8 x 10 plate was centred by the Author's Position-Finder by the first method, using the eye only, as shown in Instruction Plate No. 53.

By means of the Author's Penetration Gauge a tube was regulated to produce a radiance of X_3 for the purpose of the exposure. The X_3 represents the power of radiance at the distance at which the exposure was made. (20 inches in this case.)

In the negative three laps of the Standard Register show and prove that three layers of the metal were penetrated. (See description of this device.) It is shown to be a very low power of radiance.

The sharply defined circle is the lower circle of the Author's Distortion Landmark, proved by the clearness of its shadow to have been close to the film. The blurred circle proves the position of the upper ring of the landmark. That the two shadows of the circles are nearly but not exactly the same size proves that the tube was nearly but not quite exactly 20 inches from the film. The variation is slight. That the two rings are not in exact register proves the direction and extent that the focus was out of centre. The slant of the blurred circle proves that the focus was a trifle too far in the diagonal direction shown by shadows. (Nearly up the line of the humerus.) In the negative the greatest space between the two ring-shadows is ¼ inch, and the Divergence Chart shows that to slant the shadow this much the focus was just 6-16 of an inch out of a plumb-line dropped through the axis of the circles of the distortion landmark which define the X-Ray field in this exposure. Considering that the sighting was done off-hand, using only the eye without any measuring instrument to centre the plate, the result is accurate enough for absolute legal evidence and *the proof of the accuracy is in the negative itself*. A part two inches thick would have no distortion.

The clear circle proves the boundary of the diagnostic field. The nearness of the elbow-joint to the centre of the axis of the rays is self-evident. The final fact that a total penetration of X_3 is not active enough to make the exposure at 20 inches sufficient for the bones also appears proved by the negative. It suffices for the soft parts.

In writing the above the author states the facts from the original print. So much is lost by a reduced half-tone that the student will fail to fully profit by the lesson unless he makes a similar exposure and studies the result at first hand. This plate illustrates the value of four of the author's aids to medico-legal accuracy in X-ray work, and affords self-evident proof, not only of the result, but of the technic of the exposure. It is the first radiograph of the kind ever published, and should be studied with care.

When held up to light the original negative of this picture shows three laps of the Register. The exposure was three minutes. A second picture made had five minutes' exposure, and the negative shows five laps of the register. This indicates that when a radiance of X_3 (as measured at 20 inches by a gauge of sheet brass No. 28) acts on a sensitive film at the same distance each layer of penetration takes one minute of time. Thus, to secure in one minute the effect of five minutes with X_3, we should use a radiance of X_{15}, which can easily be regulated by the current dosage and the spark-gap.

A SYSTEM OF INSTRUCTION

IN

X-RAY METHODS AND MEDICAL USES OF LIGHT, HOT-AIR, VIBRATION AND HIGH-FREQUENCY CURRENTS

A PICTORIAL SYSTEM OF TEACHING BY CLINICAL INSTRUCTION PLATES WITH EXPLANATORY TEXT. A SERIES OF PHOTOGRAPHIC CLINICS IN STANDARD USES OF SCIENTIFIC THERAPEUTIC APPARATUS FOR SURGICAL AND MEDICAL PRACTITIONERS

PREPARED ESPECIALLY FOR THE POST-GRADUATE HOME STUDY

OF

SURGEONS, GENERAL PHYSICIANS, DENTISTS, DERMATOLOGISTS AND SPECIALISTS IN THE TREATMENT OF CHRONIC DISEASES, AND SANITARIUM PRACTICE

BY

S. H. MONELL, M.D.

NEW YORK

Professor of Static Electricity in the International Correspondence Schools; Founder and Chief Instructor of the New York School of Special Electro-Therapeutics; Member of the New York County Medical Society; Member of Kings County Medical Society; Charter Member of the Roentgen Society of the United States; Formerly Editor of the Electro-Therapeutic Department of the Medical Times and Register, 1894–8; Author of "The Treatment of Disease by Electric Currents," "Manual of Static Electricity in X-Ray and Therapeutic Uses," "Elements of Correct Technique," "Rudiments of Modern Medical Electricity," etc., etc.

NEW YORK

E. R. PELTON, PUBLISHER

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PREFACE

This work is essentially a new departure in medical literature. Neither the surgeon's library, nor post-graduate schools, nor Correspondence Instruction supplies the special instruction set forth here. The Camera has been called upon to translate the clinic into a Pictorial System of practical information, and it is believed that it has done it successfully.

The great adjuncts to the materia medica and surgery which are considered in this Pictorial System of Instruction include modern scientific X-Ray Diagnosis, X-Ray Therapeutics, the revolutionary development of Electric-Light Therapy in its three forms, the efficient Therapeutics of Superheated dry air with improved Hot-air Apparatus, the important Therapeutics of Vibration-Apparatus for Mechanical Massage, and the practical but yet unfamiliar Therapeutics of High-Frequency currents from attachments to X-Ray Coils.

The author's purpose is to teach methods that the reader can use in his own work. X-rays are worth nothing to the practitioner till he knows how to use them. Then a good apparatus pays for itself several times a year. The natural relationship between chemical rays of light and the radiations from a Crookes tube fit the two subjects for study together, and the author has sought to bring what is now known of Photo-therapy into as plain and practical familiarity for personal use as he has brought X-rays. The study of these twin offspring of electricity has become imperative in importance.

Directions for the employment of hot-air apparatus are here for the first time put into clinical form and pictorial clearness. Every practitioner who prescribes massage or needs it will be greatly indebted to our section on Vibration therapeutics for the personal use of the physician—a great advance on manual massage. An instructive study of "High-Frequency" currents will show every surgeon or physician who has an X-ray coil how to use it for valuable medical effects similar to those of Static electricity. The clear and condensed text, the directions for a vast variety of methods, and the photographic pictures of technics aim at furnishing the reader at home with the advantages of clinical instruction without the cost. The ease with which the instruction plates and text can be followed will be appreciated after a single hour's study.

CREDIT MENTIONS.

The author here desires to express his obligations to medical journals, and especially to the *American X-Ray Journal*, the *Archives of the Roentgen Ray* (London), and to the *Journal of Physical Therapeutics* (London), without whose courtesies this work must have lacked much of its completeness. We have made free use of material from their valuable pages. Colleagues who have kindly contributed to this work will find due mention in appropriate places in the text, and in addition the author here makes grateful acknowledgment to all for every assistance he has received.

TO FORMER STUDENTS AND READERS.

Physicians who have any of my four previous text-books, published during the last five years, are informed that no part of any of them is contained in this work. This volume is wholly new and original and covers other ground.

THE AUTHOR.

NEW YORK, 1902.

TABLE OF CONTENTS

Directory of the Six Instruction Courses.

CHAPTER XX.

AUTHOR'S X-RAY PENETRATION GAUGE.

CHAPTER XXI.

AUTHOR'S DISTORTION LANDMARK.

CHAPTER XXII.

AUTHOR'S POSITION-FINDER.

CHAPTER XXIII.

AUTHOR'S ONE-MINUTE LOCALIZER AND EXAMINING-FRAME.

CHAPTER XXIV.

OTHER METHODS OF LOCALIZATION.

CHAPTER XXV.

MEDICO-LEGAL RADIOGRAPHY.

CHAPTER XXVI.

BINOCULAR RADIOGRAPHY.

CHAPTER XXVII.

THE STANDARDIZATION OF SCIENTIFIC X-RAY TECHNICS.

CHAPTER XXVIII.

"X-RAY BURNS."

CHAPTER XXIX.

X-RAYS AND FRACTURES.

CHAPTER XXX.

X-RAYS IN MILITARY SURGERY.

CHAPTER XXXI.

X-RAYS IN ORTHOPEDIC SURGERY.

CHAPTER XXXII.

STUDIES IN THE X-RAY DIAGNOSIS OF CALCULI.

CHAPTER XXXIII.

DENTAL RADIOGRAPHY.

CHAPTER XXXIV.

X-RAY DIAGNOSIS IN DISEASES OF THE CHEST.

CHAPTER XXXV.

THE FLUOROSCOPE IN PLEURITIC EFFUSIONS.

CHAPTER XXXVI.

EXAMINATION OF THE STOMACH AND ABDOMEN.

CHAPTER XXXVII.

X-RAY THERAPEUTICS. EMPIRICAL NOTES.

CHAPTER XXXVIII.

X-RAY THERAPY IN SKIN DISEASES.

CHAPTER XXXIX.

THE X-RAY TREATMENT OF LUPUS.

CHAPTER XL.

X-RAY REMOVAL OF SUPERFLUOUS HAIRS.

CHAPTER XLI.

CANCERS AND RODENT ULCER.

CHAPTER XLII.

TUBERCULOSIS AND X-RAY THERAPY.

CHAPTER XLIII.

X-RAY NOMENCLATURE.

CHAPTER XLIV.

PHOTO-THERAPY.

CHAPTER XLV.

PHOTO-THERAPY: PROJECTION ARC-LIGHTS AND ARC-LAMP CABINETS.

CHAPTER XLVI.

PHOTO-THERAPY: INCANDESCENT ELECTRIC-LIGHT CABINET BATHS.

CHAPTER XLVII.

PHOTO-THERAPY: LIGHT-RAYS WITH PREDOMINATING RADIANT-HEAT.

CHAPTER XLVIII.

HOT-AIR THERAPY.

CHAPTER XLIX.

VIBRATION-THERAPY.

CHAPTER L.

"HIGH-FREQUENCY" MEDICAL ELECTRIC-CURRENTS.

Studies in X-Ray Diagnosis

"*The clinic of Trendelenburg in Leipsic in many respects is the peer of any. The ample and superbly appointed department for Roentgen photography must impress every visitor. Hundreds of magnificent skiagraphs illustrative of many and varied pathologic conditions accurately classified are exposed in convenient cabinets.*"—Impressions of German Surgical Clinics. By Dr. Eastman.

CHAPTER I

WHAT ARE THE X-RAYS?

A Short Study—Becquerel Rays and Their Uses.

The announcement of Roentgen's electrical discovery of invisible light rays, which he called "X," first reached America by cable from London on January 7, 1896. Since then the world's resources in science have studied them, and a hundred pages would not hold an abstract by title merely of the investigations and theories of the first year. These theories are of no practical value at the bedside or in the physician's office. It is agreed that X-rays are vibrations of unascertained wave-length, and as heat waves, sound waves, light waves, electric-current waves, etc., have made the student of pure science familiar with vibratory waves of many lengths and velocities, he is satisfied to regard X-rays in the same way. But what we want in practice is a working knowledge of *how to use them* regardless of what they *are*. The simplest truth that can be stated of their nature is that X-rays are a modification of electric-light rays, and the student who consults our section on photo-therapy will be satisfied to classify them in this way.

An electrical discharge suddenly meeting a sufficient resistance produces (as does a flint struck on a resisting surface) a flash of light. In the arc-light the resistance is an air-gap. In the incandescent lamp the resistance is in a filament placed in a partial vacuum. In the Crookes tube the resistance is a break in the electrical circuit placed in a sufficiently high vacuum. The operating principle of transforming electrical waves into light waves is similar in all and differs mainly in degree. The spectrum shows that composite light is made up of many rays, among which are heat rays, chemical rays, and actinic rays of active properties but without luminous effects on the eye. Some of the most useful radiations of whole light are therefore invisible, and in this respect X-rays resemble them.

The striking difference between X-rays and other invisible light rays, and which makes them the diagnostic agent they have become in the surgeon's hands, is their greater power to excite fluorescence in certain chemicals. Many rays have a little power of this kind, but X-rays of light have so much more power that they have been deemed unique and mysterious beyond well-known light-rays which really have similar properties on a small scale. We accordingly regard rays of X-light from electricity as a modified form of the invisible chemical rays of whole electric arc-light (the modification being due to the conditions of generation), and no other view of the nature of X-rays is demonstrably any truer or more useful to the practitioner than this.

Now let us consider certain facts on which the majority of investigators are agreed. The X-ray is the product of an intense electrical bombardment upon a dense metallic surface situated in vacuo beyond a gap in circuit; the bombarding stream across the vacuum gap is a cone-shaped discharge from the negative electrode in the exhausted tube; it is called the cathode stream; cathode rays are the first step-up transformation of the current beyond the point of direct conduction; they have none of the higher qualities of X-rays; when they focus to a point and strike the polished platinum wall of the positive electrode (anode) the collision under high strain and pressure transforms the lower cathode-ray into the higher X-ray.

X-rays radiate from the front of the positive electrode in straight lines as do rays of ordinary light. They diverge as do rays of ordinary light radiating from a spot or point. In the field of their discharge they *ionize* the air and make it a conductor of electricity. Many of the phenomena associated with X-rays are proved to be *electrical* phenomena. X-rays cannot be reflected, refracted, or concentrated by lenses, but they diffuse themselves by colliding with particles in their paths and producing minor secondary X-rays. They can only be employed as transmitted light, hence camera effects are impossible. But they act on photographic films like rays of ordinary light, though with activity varying according to quantity of rays, intensity of discharge, and distance from the anode source of energy. The fluorescing power of X-rays diminishes rapidly as the distance from the tube increases, a loss of luminosity familiar to all who read at greater or less distances from any other source of light. Their power of stimulating and over-stimulating the nutrition of the skin and its appendages diminishes still more rapidly than does the fluorescing property, and has a much shorter field. Bodies of even small thickness and density in the path of the rays rapidly diminish their power of causing fluorescence, and still more rapidly reduce the power of altering nutrition. After passing through tinfoil or thin aluminum the X-ray goes on with its active dosage diminished, and if a thick sheet of lead is interposed its dosage is rendered *nil*. This reduction of active dosage accounts for the "protecting" effects of screens in radiography.

Every physician and surgeon should have a general reading knowledge of the history, physics, experimental data, and development of the X-ray before using it in practice, and a number of ordinary text-books now cover this ground. The original paper of Roentgen's should be read by all. The scientific side of the study should not be wholly neglected, though little of it is practical. But this course of instruction in technics does not contemplate pages of well-worn matter obtainable in other ways or already familiar; our purpose is to teach the *uses* of X-rays so that practitioners can make them profitable, and at the start we assume that some idea of the subject has been gained before, and we leave further details to develop as we proceed. One thing may be said here ere we pass to another sort of ray.

Thus far there is no known action of the X-rays which is not also a known action of already known forms of electricity. X-rays are invisible: so is an electric current. X-rays radiate from a source in diverging rectilinear lines: so do the rays of an electric light. X-rays affect the photographic plate: so does electricity and the electric light. X-rays will pass through the body and make a picture: so will rays of electric light. X-rays fluoresce certain chemicals: electric discharges do the same. X-rays affect the tissues in peculiar ways: electric currents can (and have) set up similar actions in every way. The main difference is not one of kind, but of *degree.* If X-rays penetrate the tissues, so do electric currents; but *the power of producing fluorescence* after passing through tissues and thus giving visibility to parts within parts is possessed by X-rays in so much greater degree than by electricity in other forms of discharge that it has made them seem *unique.* They are unique only in the higher degree of an action which other electrical discharges parallel in feebler degrees. They will not appcar quite so mysterious hereafter if we consider them in the light of electrical discharges.

Becquerel Rays.—At various times during the past few years physicians have read accounts of "X-rays," not from a Crookes tube requiring costly apparatus for its operation, but spontaneous rays given off by certain substances, among which the most active is uranium. The daily press has almost led us to suppose that in due time we could discharge the vacuum tube, and with a lump of metal in our pocket have a portable source of X-rays, minus all operating expenses and lasting forever. But these much-talked-of Becquerel rays get no farther than the first stage. They feebly act on a sensitive film, they faintly fluoresce a barium screen, and they slightly penetrate solids, but as, even with the most powerful preparations thus far obtainable, it is not possible to see the bones of the fingers, the surgical value of this ray is *nil*. Exposures of the hand lasting more than an hour gave no trace of the bones. The rays diffuse so rapidly in passing through substances that they lose their utility. Even were this not the case, another difficulty exists in the fact that various substances that can be very readily examined with X-rays are about twenty times more opaque to Becquerel rays. No one can now foresee any prospect that these rays will attain direct usefulness for medical and surgical purposes, but it is possible that they may be indirectly useful. Recently there comes a report that Grummach has applied Becquerel rays to enhance the effect of X-rays in the following manner: "A screen of fine linen was impregnated with a solution of uranium—the source of Becquerel rays—and suspended between the vacuum tube and the subject so that the X-rays passed through it. The shadows cast on the fluoroscope were much clearer and more distinct, and the contrasts were sharper than by any other technique. The finished radiographs were likewise exceptionally distinct, even with obese subjects." Similar reinforcement has been accomplished with other ray-producing substances, and in this direction of research great results may lie. Uranium is now scarce and more costly than diamonds, however.

The physiological effects of radium rays may possibly develop something of more practical use than their feeble fluorescing properties. We may yet have in this substance a therapeutic agent of practical value. The first report of early experiments was made in June, 1901. In a note in a French journal, MM. Becquerel and Curie give an account of various painful experiments which have been made in connection with the study of radium rays. The first martyr to science in this connection was Giesel, who placed a radium preparation in a celluloid case strapped to his arm for two hours. At first the skin showed only a slight reddening. About two or three weeks afterward inflammation set in. M. Curie was the next victim. He exposed his arm for ten hours and on the twentieth day following had a very sore arm requiring a bandage. On the forty-second day the arm began to get well, but even on the fifty-second day a discoloration showed where the surface had been affected. M. H. Becquerel placed a very active radium preparation in his waistcoat pocket for six hours. The resulting sore took ten days to develop and forty days to heal. Several others had similar experiences, and all who have worked with very active preparations experience pains and sores in their fingers which take two months to recover.

Pergram's instructive paper on radio-active substances and their radiations gives the most concise account of this subject that we have seen. Medical readers would be astonished at the amount of investigation these many rays have received, but space limits us to practical work. It is also without value to cite tables and tests of relative "absorptive" powers of the different tissues of the body and solid substances. A little work with a tube will teach more of these matters than the most tedious text, the plain facts appearing to the eye more clearly than in description. An opaque metal or thick solid that cannot be seen through by the rays is said to have "absorbed" them, which only means that the dense barrier has stopped rays which are unable to pass through it.

CHAPTER II

THE X-RAY EXPERT

Lines of Self-Education.

The extent to which X-ray work had developed in this country was revealed with pleasing emphasis on December 13 and 14, 1900, in the city of New York, when for the first time an organized gathering of results was made and individual accomplishment and separate research met together. But at once it was seen that uniform methods of high-class X-ray technics must be placed before all operators in this field to give results a uniformity of value. Subjected to the test of comparison many of the written descriptions of methods in the books of the Nineteenth Century became ancient in a single day and the need of Twentieth Century Instruction was imperative.

When grouped together the strides that four years had taken in expert knowledge and X-ray workmanship were seen to surpass the early expectations of conservative practitioners and to require rather a standardization of what was best in the achievements of the present than waiting aloof till "advances" of an imagined character should yet come.

Another year has passed, and the X-ray is ready to serve both surgeon and physician with proved efficiency when accepted with rational pre-requisites to results. Its aid to the surgeon depends on the use he makes of it, but modern surgery without the X-ray is an unthinkable proposition at this date. It also knocks with more confident claim at the door of the therapeutist and now seems to be an unmistakable factor in the treatment of certain diseases. Its part in dental diagnosis is almost a story of romance, so far-reaching beyond the eye and all other probings does its key unlock. Its record on the sensitive film or visible image on the screen reveals the seat and nature of many hidden lesions, and it will do much in great variety for him who learns to make it the servant of his wishes. It is an instrument for the progressive practitioner.

Tentative experiment has settled many things. Improved appli-

ances have greatly outgrown their transition stage and are now constructed on better lines. Revolutionary changes have taken place in assisting factors as well as in the electrical mechanism of equipment. The chief gap in the needs of the student is instruction in how to get the best work out of the best apparatus he can now buy so that he can equal in his own office or hospital the reported work of others. The author has undertaken this Pictorial System of Instruction with a view to fill this gap and to supply the correct information in plain language. It is a difficult task not previously performed by anyone, and till better done by some more competent hand this treatise may help the novice along the path of experience and over tribulations.

We are inclined to regard the X-ray section of this work as the author's most valuable bequest to the profession, for it seems inevitable that, once their utility is known, the triple-armed value of the X-ray coil and the X-ray static machine must carry one or the other into every surgical and medical office, sanitarium, and hospital, wherever diagnosis is a science and therapy is progressive. For this reason, and to broaden the student's mind in a rational and comprehensive grasp of the important subject, a great many small but *significant* details have been grouped together in these chapters. Tests and time will disclose their worth, and nothing less than conviction of the necessity of these teachings would have induced the author to present them. Much of the writing so far published has been history, narrative, theory, argument, and report; actual working-directions have been few and far between.

The X-ray has been "epoch-making" in more senses than one, and while an "enthusiast" can in some ways over-state its diagnostic indispensability to a particular surgeon or physician no one can yet measure the total ultimate debt of twentieth-century therapeutics and practice to the professional awakening which is resulting from it. He who investigates X-ray apparatus will learn of other meritorious things related to it that need only to be known to find scores of uses in the hands of 50,000 colleagues. It is, in fact, impossible to now practise medicine without needing the aid of selected and strikingly efficient apparatus, which is revolutionizing rational treatment of disease in the wake of the X-ray. Therefore, to the practical technics of the X-ray we shall here give the close attention they deserve, believing that the instruction thus set forth will exert a greater influence for good than any other task to which we can direct our pen.

How to educate himself along lines that will most speedily enable him to do competent work with this important adjunct to both surgical and medical diagnosis is the first concern of the beginner. When he has been instructed by experience and become expert his knowledge will possess the following scope:

1. He will know how to operate the exciting electrical apparatus with skilled control of the current.
2. How to manipulate tubes with skilled dosage and regulation of radiance.
3. How to place the patient, or part to be examined, with proper fixation.
4. How to place the tube in correct relation to the part.
5. How to make an accurate Fluoroscopic examination and interpret it.
6. How to make an accurate picture with clear definition in the negative.
7. How to read its shadows for correct diagnosis.
8. How to make and manage therapeutic exposures.

These are the *essentials* of X-ray utility. There are *three* main subdivisions in the uses of the X-ray. The difference in the objects sought in each use varies the technique accordingly. These subdivisions are:

1. Fluoroscopic illumination of general shadow-pictures on a screen before the eye.
2. The creation of shadow-pictures on photographic plates.
3. The use of the X-ray as a medical remedy.

All the manifold uses of X-rays resolve themselves into this brief list, as all the words of our language need but twenty-six letters. Learn the X-ray rudiments which spell the variations of X-ray work, and all practical combinations become possible when you understand the *units.*

As medical study is divided into the two branches of Theory and Practice we will first consider the necessary X-ray *theory* as a basis for practical work. The first theoretical question that arises is the nature of X-rays. The vague answer of the scientist is that they are "vibrations of the ether." The same thing is said of electricity, sunlight, electric-light, and Crookes "radiant matter." As this answer yields very little information to the physician treating a lupus with X-rays or a surgeon locating a bullet or diagnosing an obscure condition of a joint, we will pass at once in the next chapter to a study of the place of Roentgen's discovery in scientific diagnosis.

CHAPTER III

MODERN AIDS TO ACCURATE DIAGNOSIS

A COMPARISON OF THE DIAGNOSTIC VALUES OF X-RAYS WITH THE MICROSCOPE, STETHOSCOPE, OPHTHALMOSCOPE, CYSTOSCOPE, ENDOSCOPE, SPECULA, SOUNDS, AND OTHER INSTRUMENTAL PROCEDURES. A STRIKING STUDY OF THE SUPREMACY OF THE EYE IN DIAGNOSIS.

DIAGNOSIS requires many helps—and needs *more.* As the eye is the chief factor in examinations directed to diagnosis, so we see that the greatest of the great instrumental aids to clinical examinations are directed to aid the eye of the examiner. When ultra-conservative medical men begin to ponder on the possibility of X-rays being yet sufficiently developed to be worth *looking into,* we need only remind them that they bring new and rich tribute of information to the eye, and whatever reinforces sight is worth "looking into."

Leaders in radiography may deem it superfluous to cite evidence of the value of Roentgen's gift to the profession, and so it is to them; but as a practical teacher of physicians during the entire X-ray era the author is well aware that many a practitioner has not yet seen a Crookes tube glow at all, while thousands of others cannot yet set a tube in action or interpret a negative. All such will desire and welcome an adequate presentment of the just claims of X-rays to confidence as demonstrated by reliable workers, and the sacrifice of space will be of little moment compared with saving hesitating and still uninformed colleagues from wasting years in perplexity and doubt before taking to themselves this important adjunct to medical and surgical practice. For the benefit of the beginner and to afford comparison with other diagnostic instruments, we herewith present two masterly reviews. The first is from the President's address for 1899 before the London Roentgen Society,* and illustrates what was accomplished long ere this date.

"There is no branch of medicine or surgery which does not afford abundant evidence of the improvements which have taken place in the production and utilization of X-rays. The fluoroscope has now

* Archives of the Roentgen Ray.

reached such a degree of perfection that with suitable apparatus the minutest movement of the heart and lung, and the least change in the action of the diaphragm can be watched and studied at leisure in the living subject. Photographs of the most deeply buried bone can now be obtained without difficulty. Measurements of such structures as the pelvis can be taken directly by a simple process without subjecting the patient to the least inconvenience. And the clinical records are full of instances showing what has been done and what can be done in medical and surgical practice.

"An account of these which would be in any way adequate would fill a volume, but there are some of so striking and definite a character, that a brief summary may be attempted. Many disorders which even after the discovery and the first application of X-rays were regarded as almost impossible of certain demonstration, such as aneurisms of the thoracic aorta, interlobular empyemata, mediastinal abscesses, and patches of central pneumonia, can now be shown upon the screen with the greatest distinctness, and localized with absolute accuracy. Photographs can be taken of enlarged mediastinal glands and of other intra-thoracic growths. The illumination of the fluoroscope now is so steady and uniform that the earliest stages of tuberculous lesions in the lungs can be seen and recognized, partly by the curiously stippled shadows which they cast, partly by the visibly impaired movement which accompanies them—a fact which has not escaped the notice of some of those who are connected with life insurance. Cavities in the lungs, whether containing air or pus, can now be detected at once, and the position and depth from the surface accurately mapped out, so that a question of the advisability of drainage and operation is once more coming to the front. The presence of adhesions; the alteration in the level of pleural effusions in different positions of the body; the distinction between sub- and supra-diaphragmatic collections; and the existence of cysts or tumors projecting from the upper surface of the liver and raising the diaphragm can now be shown with the greatest clearness. And the same may be said of changes in the position of the heart, and in the size and shape of its chambers, whether brought about by disease or by strain thrown upon their walls by difficulties in connection with distant vessels. They can be distinctly seen with the screen and can be watched from day to day, especially in those cases in which, owing to the presence of emphysema and the absence of cardiac dulness, the ordinary tests fail to give any information. There is, in short, scarcely a thing in connection with the lungs and the heart and great vessels which cannot now be seen and photographed; scarcely a disease of the chest or the organs which it contains concerning which the most valuable information cannot be obtained.

"To such an extent has the fluorescent screen been improved, and so easy has investigation with it been made, that I am convinced that some day (and probably at no very distant date) the examination of a patient's chest with it will be considered as much a matter of routine and as little to be neglected in all doubtful cases as an examination with the stethoscope at the present time. Valuable as are the indications given by the ophthalmoscope in obscure diseases of the brain, they are not to be compared with those that can be obtained by systematic and skilled use of the fluorescent screen in diseases of the heart and lungs.

"The benefit which surgery has derived from improvements which have been effected in the use of X-rays is no less striking. Military surgery has been rewritten. Thanks to the ease with which apparatus can be employed in *base* hospitals, all the wearisome and intensely painful probing after bullets and foreign bodies to which the wounded looked forward with such dread have been swept away. The actual position is defined at once, and the track that it has made is left to heal up of itself. Shot and portions of percussion caps and even the minutest fragments of metal have not only been localized in the eye, but their exact shape and size have been ascertained with so high a degree of accuracy that they could be removed by the most direct route through the smallest possible incision. Bullets, the position of which inside of the skull could not even be conjectured, have been successfully localized and extracted from the brain.

"Foreign bodies, such as plates of false teeth, which have been swallowed accidentally or have dropped into the air-passages; others introduced in the course of operation; splinters of bone, pins, and needles of various kinds, wire sutures, fragments of glass which have been buried perhaps for years, and numberless other substances have not only been made visible, but have been marked out as accurately as if they had been lying in some perfectly transparent medium, so that they could be excised or not according to the degree of inconvenience which they caused and the relative danger of the operation.

"The largest proportion and the most striking cases of advantage have been furnished by injuries and diseases of bones and joints. Those only who have experienced the difficulty of determining whether a fracture or a dislocation or both may not be present in the neighborhood of such a joint as the elbow, when the soft tissues around are so swollen that no bony prominences of any kind can be felt, can realize the immense help given by a well-lit fluorescent screen. It is no question now of long exposure or of keeping the patient, perhaps a child, frightened and suffering pain, quiet for a considerable part of an hour, or even under an anæsthetic. A minute is enough. The nature of the injury is apparent at once, and, what is even more valuable, it is no less easy afterward to ascertain whether the fracture is properly set or the dislocation completely reduced. If the screen is of service to physicians in the diagnosis of intra-thoracic disease, the records of the past year have shown by numberless instances that it is no less valuable to surgery by enabling them to make sure at a glance that the bones are in their proper relation without touching the splints or giving the patient a moment's pain.

"*Diseases* of bones and joints are benefited by the X-rays no less than injuries. Thanks to improved methods the hip-joint can now be radiographed with certainty. All the strange appearances which were so misleading, and which were due in large measure to the distortion produced upon the photographic plates *by faulty position* can be eliminated. The various forms of congenital dislocation can be differentiated from each other, and from such complaints as coxa vara, which are attended by deformity of a somewhat similar character. The fate which overtakes bony grafts implanted into defects have been watched as plainly as if the grafts were on the surface of a limb instead of deeply buried in its substance.

"Diseases such as sarcomata, tuberculous deposits, central abscesses, necrosis, and the like, which, when they occur in deeply seated bones are often exceedingly difficult to recognize and distinguish from each other, have been made perfectly plain. Cavities hitherto almost inaccessible without operation, such as the frontal and sphenoidal sinuses, have been brought within reach of the probe. Valuable help has been given in the diagnosis of antral and other maxillary tumors, and a serious blow has been inflicted upon the reputation of the "bone-setter" who, now that the position of even the smallest bone can be shown to the patient in a photograph, has been compelled to alter his phraseology if not his questionable practice.

"Nothing more illustrates the immense improvement which has been made in radiography than the detection of renal calculi. Until 1899 the instances in which they had been photographed and verified by operations were few and far between. Success had been attained only in the case of very thin and anæmic patients. Now the detection of renal calculi can be looked forward to with a fair degree of certainty, and which is even more valuable, as saving patients from unnecessary operation, the evidence can be trusted equally well when it is in the negative. In all ordinary cases it may now be said that if no calculus is seen there is no calculus to see.

"There may have been no startling new discovery—such do not occur every year—but *there is no single method or part of the technique in which the advance has not been immense. Important as radiography has already become, I believe the position to which it has attained is as nothing as compared with that which awaits it. There can be no doubt that the results will continue to improve and very likely at a more rapid rate than they have done already, and that in a little while, not only will every institution connected with medicine, but every practitioner will be equipped with suitable apparatus.*"

Obtaining his experience independently in another land Kümmell thus reviews the value of X-rays in practical medicine and surgery:

"In addition to their value in the detection of foreign bodies they have become of special value in military surgery. Pathological dilatation of the œsophagus may be shown by them. Both dilatation and stenosis may be made apparent by inserting into the organ either in bulk or in gelatine capsules some metal salt like bismuth which is sufficiently opaque to the rays to define the existing condition. Sounds may be also employed in connection with the X-rays in dilatation of the œsophagus, as well as in gastric dilatation if the sound lies against the wall of the œsophagus or the greater curvature. Foreign bodies in the intestinal tract may also be located by means of the X-rays as well as Murphy buttons and foreign bodies introduced for therapeutic purposes. The X-rays are of value when there are suspected pathological concretions, although up to the present time gall-stones have been detected rarely by this means. Vesical calculi can generally be easily detected by the X-rays. The facility with which these foreign bodies can be detected varies according to the chemical constituency of the concretion. Concretions composed of urates and oxalates are less translucent than phosphatic calculi. Both incrustated as well as non-incrustated bodies, hair-pins, etc., are easily demonstrable by means of the Roentgen rays. Considerable progress in the detection of renal calculi has also been made, and here also the thickness of the soft parts as well as the translucency of the concretion renders its detection more or less difficult.

"The triumphant success of the X-rays in medicine is well known to have been due to the detection of fractures, luxations, and diseases of bone. Roentgen rays have been of great value in diagnosing and treating congenital luxations of the hip. The differential diagnosis between congenital luxation and coxa vara is presented in an interesting manner by the X-rays. Syphilitic, tuberculous, and osteomyelitic thickening and deposits in the large and small long bones are not difficult to recognize by means of the X-rays, and it is interesting to observe how under treatment a tibia that before medication appeared as a narrow shadow upon the radiograph, gradually increases in volume. Similarly, small pathological changes, such as tuberculous deposits, may also be diagnosed.

"Among the tumor-formations large, broad osteo-sarcomata are characteristically portrayed by the X-rays. Nothing of account has yet been attained in detecting other tumors of the body by this means, as the contrast of individual tissues is not sufficient to be of diagnostic value externally. The shadows of the liver and kidney as well as the convolutions of the fetal gut may be plainly seen, but less so in the adult. Fecal masses are easily recognized.

"Chemical substances introduced from without for therapeutic or diagnostic purposes, especially the iodine compounds, can also be plainly seen. Iodoform-glycerin injected into tuberculous joints remains there for a long time and is absorbed slowly. Here the Roentgen picture teaches us that it is not necessary to leave a great amount of this mixture in a joint, as small quantities being also slowly absorbed, fully meet the therapeutic requirements. Iodoform-glycerin injected into fistulous tracts is of diagnostic value in that it penetrates to the bone and permeates extensive sinuses. Characteristic results have been obtained in the recognition of myositis ossificans. Arteriosclerotic changes in the blood-vessels yield very plain X-ray pictures. Considerable progress has been made in observing the intrathoracic changes. The dilated lungs of emphysema, and the lungs in pleurisy and empyema are plainly seen by the X-rays and a pneumothorax which clinically could not be established with certainty was diagnosed without a doubt by means of the Roentgen picture. Lung cavities are easily detected. Peri-bronchial changes appear as sharply defined nodules of variable size. The shadows of the heart, aorta, and aneurisms as well as mediastinal tumors have repeatedly been employed for diagnostic purposes.

"The employment of the X-rays for therapeutic purposes has yielded excellent results in the treatment of lupus. It is to the treatment of skin diseases that the therapeutic efficiency of the X-rays has been principally confined. Other skin diseases that have been successfully treated by this means are chronic eczema, vascular nævus, hypertrichosis, favus, and sycosis. Considerable has been attained since five years by this epoch-making discovery of Roentgen, but much more will be attained during the present century."

From the perusal of these authoritative yet merely skeletal etchings of a great subject let us now turn to other diagnostic instruments which are so familiar that they need no index to their services. Without reminders in this text the reader can weigh the diagnostic services of the microscope and the training it takes to use it well; he can imagine himself without the stethoscope and estimate how much he would miss it; if in general practice, he can recall how often he uses his ophthalmoscope, and cystoscopes, endoscopes, specula, sounds, etc., and their value can be speedily passed in review. Then may come exploratory incisions for diagnosis, examinations of the blood, urinalysis, germ cultures, and all other adjuncts and aids to modern means of finding out what ails the patient. Add to them the X-ray. Then compare its relative possibilities. Learn also to appreciate and use them.

The Twentieth-Century surgeon is armed with tremendous possibilities, and when we have had the X-ray as long as we have had the microscope, stethoscope, and other instruments, the full measure of its resources may present a more striking comparison than to-day.

One thing more remains to be said: A poor microscope can be purchased; a poor stethoscope is not hard to find; cheap instruments of all varieties abound; but in estimating the value of the work each type of instrument will do no author makes a poor and cheap specimen the basis of his teachings. Apply the same rule to the X-ray. Much of the past X-ray literature has been necessarily based on apparatus very greatly inferior to the best now made, and allowance

must also be made for the fact that early technics were hardly a fair basis for final scientific conclusions regarding the capabilities of X-rays. With these thoughts to modify our judgment let us seize the lamp of experience as we now find it lighted, and with its yet too-feeble rays to guide our study, press forward to higher developments with practice.

CHAPTER IV

X-RAYS IN THE AVERAGE OFFICE

A Story of Practical Utility and Profitable Results.

While *instruction in technics* is the first aim of the author in the preparation of this work, yet to many medical men in what may be called country towns the question of whether they need X-rays at all requires an answer before technical methods enter into the subject.

Does the practitioner doing general medical and surgical work in communities of from 2,000 to 20,000 population need an X-ray apparatus, and what will he do with it? How will he make it pay?

To answer these important questions the general literature of the subject ought to be sufficient, but much of its force escapes the reader *till he sees the actual work done, or does it himself.* A personal narrative, giving the experience of a colleague similarly situated, will be more helpful in settling the problem than many reports from laboratories of specialists which seem too far out of reach or too wonderful to be true. To bring the facts down to a practical basis for the average reader's own office and his own use, we present part of a typical report by just such a practitioner as 50,000 others in this country. What one has done others can do. The writer's description of his equipment is omitted, and we take up his story in the middle:

"Thus, beginning with the appliances described above, the best obtainable at first, and adding to them from time to time as improvements appeared, the work has become gradually more engrossing and effective. The first fluoroscope and tube purchased showed the thinner parts of the body, but would allow no examination of the trunk. Most of the bones could be distinguished, although at the time it required patience and perseverance.

"One of the earlier experiences was in locating a thirty-two calibre bullet in the upper fourth of the thigh. The limb was very thick and the rays poor. After an hour and a half of patient search (with the fluoroscope), despite the fact that the whole length of the shaft of the femur could be made out, it seemed that we must give up, when a slight elevation on the surface of the bone became visible. The spot was marked, and a subsequent successful operation explained the difficulty. The bullet had been mashed flat against the surface of the

bone and was so thin that it caused little more shadow than the bone. (A radiograph would have shown it better.)

"In April, 1896, the liver appeared, though somewhat imperfectly, in a photograph. In August a new fluoroscope arrived, and on searching for a bullet in the chest, one day, there suddenly appeared to the delighted vision the shadow of something expanding and contracting at regular intervals, and this proved to be the heart. The liver appeared at the same time, and with it a vivid realization of what an extensive excursion this organ makes with each respiration. The kidneys were discovered later.

"We have examined in all about 400 cases; many with negative results. These examinations include every part of the body, from a thumb in which a needle was lost, to the spinal column, for diagnosis of a curvature. Lack of time prevented our work from being as systematic as the subject deserved, and some of the more interesting cases were not photographed.

"There have been applications for examination by the X-ray from various sections of the country, from people with all manner of diseases; many, of course, absolutely unsuitable for its use. The general public is impressed with the idea that the ray is capable of showing the condition of every organ of the body, and also of demonstrating the mysteries of numerous functional diseases. We have had to examine several patients for imaginary tumors, who would not be satisfied with the ordinary methods of physical exploration. One gentleman assured us that he had been suffering with his abdomen for years, and felt certain that 'something was broke loose inside of him.'

"So far our best results have been in connection with *bone surgery*, the ray being of invaluable assistance both in the diagnosing and also in aiding the treatment of fractures, dislocations, and sprains, as well as deformities and diseases of the bones.

"Our *fracture cases* have included most of the bones of the human anatomy. Only after using the X-ray can one adequately realize what a tremendous aid it can be in showing the exact condition and position of the break, especially when swelling interferes with proper palpation of the part.

"Our method of procedure has been to examine the break with the ray first, then set it, and examine again in order to see if the bones are held well together. Ordinary bandages, starch bandages, and wooden or pasteboard splints offer but little obstruction to the light. I have watched my cases from time to time, not only to be sure of no bad results, but also to note the formation of the callus. It is sometimes two weeks before this new tissue gets dense enough to obstruct the ray sufficiently to be visible, and it takes two or more months for it to appear the same as the rest of the bone tissue.

"Examination of a number of cases of old fracture shows up many defects in the setting of bones which otherwise would not be apparent. One case, in particular, illustrates this point. Before I had my machine I attended a case of fracture of the tibia, caused by a log rolling over the leg. I treated the case in the ordinary way and the man recovered, but for two months afterward he complained of unusual pain and soreness in the leg on walking. Digital examination revealed nothing. About this time I purchased an X-ray outfit, and on examining the leg found a long, sharp splinter of bone which lacerated the muscles when the man walked.

"Among the simple fractures examined I may mention several cases of Colles's fracture, fracture of hand, foot, leg, thigh, and ribs.

"A recent interesting case was a fracture of the elbow, in which the tip of the olecranon and a small piece of the external condyle were chipped off. The ray was, in this case, invaluable, enabling one to get a perfect view and to restore the joint to its original usefulness. Compound fractures have been especially interesting in showing the healing of the bones. In a number of these cases I have brought the bones together with silver wire, which shows up clearly with the fluoroscope as well as in the photographs.

"One case of excision of the elbow is interesting as showing the healing of the bones after the formation of an artificial joint. In one case of this sort the joint was so useful that the patient's friends, many of them, believed him to have had inserted a joint of gold!

"Various kinds of *new growths* are among the most interesting cases; one was an osteo-sarcoma of the fibula.

"An interesting photograph in my collection is one of the hand and forearm of a veteran of the late war, who had a considerable portion of the bone torn away by a shell. His hand was saved only after the most persistent and long-continued treatment, and the X-ray showed the peculiar way in which the bones united.

"Our cases of *dislocation* have not been so numerous as the fractures, but quite as satisfactory. They include nearly all the usual joints, wrist, elbow, shoulder, clavicle, hip, knee, etc.

"One case was sent me by a colleague who, upon first seeing it, was unable to make a diagnosis on account of the extreme swelling. The ray cleared up the matter in a few minutes. It was a case of backward dislocation of the elbow-joint. Another one of my photographs shows a backward dislocation of the knee, produced by contraction of tendons following tubercular abscess of the joint some years before. The bones had become so roughened at their ends, and so fixed in their bad position, that it was necessary to do an excision of the joint. The patient has recovered, and now has a useful limb.

"The ray has helped us with *sprains*, in showing the amount of abnormal mobility permitted by the injured ligaments. Especially in traumatic flat-foot has it given aid both in diagnosis and treatment.

"We have had so many cases of *supposed sprains* which turned out to be fractures, that I am convinced these small breaks have been very generally overlooked. The practical advantage of demonstrating the existence of such a fracture is to prevent too early use of the injured part, which might result in permanent harm. A good illustration of this point is furnished by a patient who came to me recently with a history of an injury to the ankle seven months before, and her physician wrote that he first saw her twenty-four hours after the accident, at which time the parts were greatly swollen. He could make out no fracture, and treated her for a sprain. During the next seven months she made constant but unsuccessful efforts to walk. The X-ray disclosed the fact of an old fracture of the tibia which had united but had probably taken a long time to heal, on account of the parts not being immobilized. During that time the foot became fixed in a bad position and rendered all efforts at walking very painful. Vigorous treatment by massage, electricity, etc., has completely cured her in a comparatively short time. I have had several other similar cases.

"Recently I was called to a young man suffering pain in his ankle, which he had twisted the night before while romping. I examined him carefully and felt sure there was only a sprain, but subsequent exposure to the ray proved, to my surprise, that there was a crack of the fibula near the lower end, which was not deep enough to cause the slightest sign of a deformity. The patient was a heavy man, and, but for the X-ray examination and the consequent immobilization of the joint, I feel sure that he would have had serious trouble.

"The locating of *foreign bodies* in the tissues is also one of the more interesting functions of the X-ray work. Our cases in this line include the finding of pieces of glass, wood, metal, needles, etc. I have a photograph showing a pin in the thumb which is of interest because the pin was so completely lost that an operative search was abandoned. After locating it with the ray, I found it to have pierced the bone and broken off in its substance.

"*Bullet cases* have been particularly numerous. The missile can usually be seen at a glance, and we have adopted a simple method of marking its location.

"Probing for a bullet is both dangerous and unsatisfactory, as, on the one hand, infection may be carried, and, on the other, there is a possibility of diverting the instrument in the wrong direction, on account of the deep layers of connective tissue. I should like to see the old method abandoned altogether, as a relic of barbarism, the examination by the X-ray completely supplanting its use.

"In my first bullet case, the ball had entered the thigh near the hip-joint, and had remained lost nine months, causing irritation most of the time, though not enough to enable me to find it. It was located by the ray just above the knee-joint. My last case, now in the hospital, was one of a man shot with a Flobert bullet, the missile passing between the floor of the popliteal space and the blood-vessels, and being found on the other side of the joint. Two cases of bullet in the leg were most interesting on account of the upward course pursued by the bullet. One man was walking, the other was running, when shot from behind and, curiously enough, the bullet evidently struck the skin when the foot was elevated.

"A little boy with a bullet in the lower end of the tibia informed us that while playing with a supposed unloaded pistol, a fly lit on his knee. He took aim at it, fired, missed the fly but sent a bullet down to the cartilage of the joint. I was able to remove it without seriously disturbing the joint. A bullet embedded in the deep muscles of the neck was easily located, and is yet to be removed. A few months since, in making a life-insurance examination, the applicant informed me that he had been shot in the axilla several years before, the bullet penetrating into the chest and being lost. On careful examination with the ray, I located it, close to the sternum, where, in case of any future trouble, it could be readily accessible. He would have been rejected but for this discovery.

"One of our photographs shows plainly a bullet which entered at the heel, and was found in the sole of the foot near the toes. The largest bullet I have extracted was a forty-four, which pierced the middle of the sternum, passed downward and outward through the right lung and embedded itself in the chest-wall, where I located it. The patient was in a most desperate condition for more than a week, but recovered completely.

"A most satisfactory case was that of a heavily built, thickly set man who was shot in the back of the neck. The ball passed forward, grazing the deep blood-vessels of the neck, struck the lower jaw, breaking it badly, and was located in the muscles of the face. The markings were rather difficult to make, but the operation showed the bullet to be exactly indicated. In one direction the ray had to penetrate from the front of the face to the back of the neck, and in the other direction through the face from one side to the other. The bullet could be distinctly seen by aid of the fluoroscope.

"A similar case was that of a little girl whose brother shot her in the face with a buckshot from an air-rifle. The missile went into the face deeply. The ray showed it distinctly, notwithstanding its small size and the obstruction to the light from the surrounding tissues. It was easily removed.

"We have had one case of bullet in the brain, which we found to be just back of the orbit, that we did not think it safe to remove. The X-ray will penetrate any part of the head, but here, as elsewhere, it shows the outlines of those substances only which are denser than their surroundings.

"In examining the *heart* we have been able to discern variations in size, shape, and position. We have also watched its action, and noted regularity or irregularity of contraction and expansion. The sternum and spinal column both interfere to some extent with a complete view of this important organ.

"The *liver* proves the most satisfactory of all the internal organs, to examine. We are able to make out its entire outline, including both of the lobes, and to judge somewhat of differences in density. I have seen the solidified *lung* in tubercular cases, but the healthy organ seems to be too porous to show. Of late we have made out

the *kidneys*, but with difficulty, on account of the spine and pelvic bones. The thickened wall of the *stomach* we have seen in two cases only. The other organs have remained invisible, so far.

"In the early part of our work one of the first cases examined was a young man with a bullet in the thigh. At that time his knee was very much swollen, exquisitely tender and painful. He could not bear the slightest touch or motion without crying out in agony. It was with the greatest difficulty that he could be properly nursed. I feared suppurative arthritis. In those days the machine was of much less strength than at present, and in order to get a photograph of the part his knee was exposed to the ray for four hours continuously. The next day I was surprised to see the patient moving about the bed without pain; the second day he was up in a chair, and the third day he was walking around on crutches!

"A month or two later I was consulted by a naval officer about his son's elbow, which was affected with tuberculosis, and was so much inflamed that no less an authority than Professor Wyeth had advised excision. The father consulted the great electrician, Nicola Tesla, who advised a trial of the X-ray. Acting upon this advice we exposed the joint to the ray two or three times a week for two hours each time, until the total exposure was about twelve hours. After each exposure I applied a wet dressing. In a short time all signs of inflammation had disappeared, and now nearly eighteen months have passed without any return of the disease.

"About eight months ago a colleague brought me a case to examine for gall-stones. For several months the patient had been suffering frightful attacks of pain at frequent intervals. I made a prolonged examination with the ray, without finding any stones. They may have been present and have escaped detection on account of their small size. Strange to relate, however, the man has never had an attack since the examination, and is entirely restored to good health. Two other cases of a similar nature were apparently relieved by the use of the ray.

"There has been absolutely no irritating effect from the ray in any of my cases with two exceptions. The first was the case of tuberculosis of the elbow referred to above. In this case there was a spot of discoloration of the skin, with no sign of inflammation, which disappeared without treatment, in about a week. The other was a boy who had a badly united fracture of the femur. Some difficulty was experienced in getting a good photograph of the limb. Several exposures were made. Two weeks later a dermatitis developed, confined to the surface of the skin and resembling an eczema. It was rather obstinate in healing, but after a few weeks of simple treatment was cured without any bad results.

"I have used the ray in a large number of cases of all kinds. I have myself been exposed to it for hours at a time. From my intimate experience with it I can state most positively that if properly and rationally employed, *there can be not the slightest bad after-effects.*

"I fully realize that this report is an imperfect and incomplete one, but it has the practical advantage of being drawn entirely from personal observation, and I trust that it may be of some interest and use to the profession. I am convinced that, notwithstanding the great good already obtained from the X-ray, there yet remains a broad field for further development."

CHAPTER V

BEGINNERS AND CURRENT X-RAY LITERATURE

Dogmatism. X-Rays and Popular Impressions. The X-Ray in Quackery. Special X-Ray Journals.

When writers on X-ray matters report cases and state facts of experience, as in our last chapter, they contribute much to the enlightenment of the profession and beginners cannot read too many articles of practical instruction. But when theory takes the place of fact and every separate theorist has a different opinion about almost every detail of X-ray work it perplexes the student to sort out the right conclusion.

The point is so important that it needs considering. Only a trained expert with varied experience can rapidly run through a lengthy article and separate the unreal from the real. Yet a little guidance will help the beginner to hereafter ignore some of the contradictions that fill him with doubt and tend to bar his progress. Almost no statement can now be made respecting any feature of X-ray work without finding opposite opinions held by different operators. As many of these obtain equally good practical results this difference of mere opinion must not be taken too seriously by the beginner, for controversy that ends in the same result may safely be put aside.

The *sum* of the world's knowledge of X-ray actions, technics, and apparatus *is now very great*, and any one writer of narrow reading should be quite cautious before stating that *no one else knows* what he merely does not know *himself*. Almost always an article contains internal evidence of the competency of the writer, provided the reader be a judge of competency. But in the event that he is not, then it is a safe rule to follow the reports of actual work done, and to put to the proof all theories before accepting them. The instruction thus gained will be sound and reliable.

X-rays and Popular Impressions.—On the part of the lay-public there is but little knowledge of the true function of X-rays. The sensational press and their funny paragraphers have laid deep and wide the foundation for a century of erroneous ideas about the capabilities and limitations of this means of diagnosis. Many cases of neuralgia think that the cause of their pain can be seen with the fluoroscope as readily as the bones of the hand. Even cases of nervous dyspepsia have requested the author to make an X-ray examination in the off-hand way in which one would ask a physician to look at some casual mark on the skin.

Needless alarm has also been cultivated by irresponsible newspaper reporters in regard to the terrors of submitting to an exposure. An intelligent young lady, aged fifteen, with a dislocated shoulder, exhibited the greatest terror when asked to stand a moment in front of the tube for a fluoroscopic examination which would have produced no sensation whatever. She declared that she "knew it would burn her up, and would hurt awfully." When a nurse took the position and assured her that she felt nothing, the girl allowed a brief examination, but was so nervous and alarmed that she was almost in hysterics. Those who are responsible for the evil thus done are more contemptible than vulgar criminals and cannot offer the excuse of ignorance. It should be the duty of every physician, whether he uses X-rays himself or not, to instruct his patients for their protection against dread and distrust of them.

The X-ray in Quackery.—*The American X-Ray Journal* for June, 1901, makes these wholesome remarks on this subject:

"*The Journal* of ——— recently contained an editorial upon the above subject. Surprise was expressed that *quacks* had not long since taken up this implement, but the editor submitted an explanation that it was due to the requirement of some knowledge of electricity before the X-rays could be used. The article implies *ignorance of science and letters* on the part of quacks. This idea is an error. Medical laws are now quite severe throughout the States, and yet quackery is, if possible, more aggressive now than formerly. If one acquainted with the correct uses of X-rays will carefully look over the literature of the subject, he will see the inroads made by another kind of quacks in the field of this important branch of our profession. It is not always the one who pictures his alleged skill in the columns of the lay-press who most injures the fair name of medicine. *Ignorance* has prompted more articles on X-rays than quacks. In proof of this, see the articles by learned professional men upon the 'inaccuracies of the X-rays,' for instance. It is absolutely known that there is no such thing as an inaccuracy of an X-ray (which can neither be reflected, deflected, or refracted, but pursues its rectilinear course straight to the end). Inaccuracies are the work of the operator, and become less and less in proportion as skill increases. Do we hear about inaccuracies of the law of gravitation? of magnetism? of electrical conduction? of mathematics? of the conservation of energy? of the diffusion of gases? Yet men may make personal errors in mathematical calculations and in the application of Nature's laws.

"Then, too, see the X-ray pictures so frequently used in medical journals. They tell nothing. Many are perfectly blank, black blotches, without detail, and without evidence of the description. No other kind of picture purporting to show something would be used by an editor. Why then these? They should be as delineative as other illustrations are. This effort to do something or say something upon a subject for the self-exploitation of the writer is quackery. More harm is done by scissors work and second-hand theories of illy-informed reputable medical men than by the preposterous circulars of open quacks. One deserves as little weight as the other.

"It is now the custom for the writer of a new surgical book to want an X-ray section written by some eminent man in the profession. It is an honor to get into an accredited work as an author on this subject. The choice is made without regard to the man's lack of ability in actual X-ray work. The task is undertaken, and how shamefully it is handled! These books are not written for novel reading, but for the instruction of the practitioner. He who assumes the rôle of such a writer should first know the subject whereof he writes. Howsoever wise he may be in all other domains, if ignorant in this and yet writes as a teacher, he is essentially a quack."

It is an interesting fact to note that about two-thirds of the special claims made by the few travelling quacks, who sought to achieve profit out of X-rays during the first two or three years following Roentgen's discovery, are now the accepted clinical demonstrations of a large number of physicians of the best professional standing. No ethical nose could go up high enough to express its contempt for any "quack" who claimed to "cure cancer" with X-rays in 1897. The author well remembers receiving a letter full of condemnation and asking advice as to organizing the local profession and running such a charlatan out of town. In another chapter of this course of instruction the reader will find that the treatment of similar forms of cancer is now one of the orthodox commonplaces of X-ray therapy, and he will be fully taught how to do it himself.

Special X-ray Journals.—As medical journals and surgical journals aim to supply practitioners' needs of current literature in these fields, so it is important that practitioners using X-rays in medicine and surgery should have a means of keeping posted on current developments and progress. How little the regular medical journals fill this want is scarcely realized till a search is made for some special article. For instance, a very enterprising weekly journal published in Philadelphia would be cited by many physicians as likely to contain a fair number of papers on this subject. If we are not mistaken its file shows that during the twelve months of 1901 it did not publish a single exclusive original X-ray article, and its "abstracts" on this subject were disappointingly meagre, often being limited to title.

Therefore all X-ray workers will agree that a special journal should report and illustrate the advances in this line. It is not merely wise to support such a journal, but it is *a profitable investment* which cannot be duplicated in any other way. But unless subscribers follow their subscriptions with valuable reports of their own researches, discoveries, new technics, new and useful devices, etc., the journal will not best fulfil its mission. We all know that much of the most important work done is never written up for the general benefit, and a well-sustained X-ray periodical should be rich in original contributions. There are two of these exclusive X-ray journals in the English language, and we are indebted to both of them. Others in time may appear.

The American X-ray Journal has so far been the only exclusive X-ray publication in this country. It was established in May, 1897, in St. Louis, Mo. It is issued monthly, and was the first regular monthly in the X-ray field. To the editor we extend thanks for permission to cite freely from its pages.

In England the transactions of the Roentgen Society of London are officially reported in the *Archives of the Roentgen Ray*. While the American journal was in fact the first regular monthly X-ray magazine to appear anywhere, yet the first periodical publication in the English language after Roentgen's memorable discovery was the *Archives of Skiagraphy*, under the editorship of Mr. Sidney Rowland, and which was speedily enlarged, and from its second volume developed into the present fine *Archives of the Roentgen Ray*. It is published every two months during the session of the London Roentgen Society by Messrs. Rebman, Limited, 129 Shaftesbury Avenue, London, W. C., and we cite valuable matter from its pages by the courtesy of the publishers.

CHAPTER VI

STUDIES IN X-RAY MECHANICS

Current Generators. Trouble Hunting.

The hospital or individual contemplating the purchase of X-ray apparatus needs general information on the different designs from which a selection may be made. The surgeon who has already selected his apparatus needs special information as to its adjustment, care, and operation.

To acquire the first kind of information send for the latest catalogues and quotations of the leading manufacturers and dealers and compare them, with due allowance for the conflicting opinions of competitors. To best acquire the specific knowledge of apparatus just purchased have the seller show how to set up each part of the mechanism, how to regulate it for satisfactory operation, how to care for the whole apparatus, and how to locate faults and correct them. But before making a selection it is best not to be guided solely by printed praises of any apparatus, but go to see it work. Examine various designs and find out the weak as well as the strong points of each. Then a purchase will not be likely to disappoint; or if it does not at first give full satisfaction it can be soon mastered without doubt.

The regular text-books on electricity and X-rays devote liberal space to descriptions of coils, static machines, and lists of accessories. Reiteration is not required for the practical instruction of the students of this course, and we can make better use of the space in teaching methods and technics. But beginners can quickly read a few words of general guidance.

If you think of buying an X-ray equipment first consider just what range of work you will need to do with it. Then investigate your local resources of electrical supply. Can you get the street current in your office? If so, make a note of its type and voltage. If you have no light-circuit and must use a battery, see what room you can give it, and whether you can get a storage battery conveniently charged. A primary battery is the last resort, but can be used if there is no other way. Then take all this data to the selected maker and discuss the design of coil that will best suit the conditions of your office and work. The construction of the coil, the exciting current, the interrupter, the regulating devices, the vacuum tube, and the tube-holder must *fit* as harmoniously as the parts of a watch fit when it keeps time. The essential factors are a fat current of high E.M.F. and a reliable and effective interrupter. The electrolytic types of interrupters do not use a condenser, but mechanical breaks do. If you need a condenser stipulate that it must have ample capacity. Many commercial condensers have too little. Then a heavy current in some emergency causes damage, and repairs cost money.

Condensers vary in size and price and are rated according to "capacity," and depend for their action on the law of electrical capacity. Every electrical conductor has the capacity to hold a certain magnitude of current as a "charge." In measuring the capacity of a condenser the raising of the electrical pressure one volt by a charge of one coulomb is taken as a capacity of one farad; but for practical purposes this is divided into micro-farads, and one micro-farad is the common unit. The practical effect of the condenser is to maintain in the circuit the amount of electrical action which is equal to the capacity of the condenser. Some have only a fixed rating, while some are made with a variable capacity so as to permit of a range of adjustment.

In insisting that the coil itself shall be wound so as to give a thick spark, do not forget that the character of the interrupter greatly influences this. A long thin spark may be changed to a fine thick discharge simply by regulation or change of the interrupter. Old forms of breaks robbed coils of nearly half their intrinsic value in many cases. In former days the question was simple, but now the selection of an interrupter and the regulation of it is one of the most delicate problems connected with X-ray apparatus.

There are now many improved mechanical interrupters; a dozen or more very excellent ones of the spring vibrator type; a few rotary wheel breaks; at least six fast improving mercury type interrupters; a very fine spark-gap device; and, lastly, electrolytic interrupters with numerous modifications. In each type there are very good and very poor instruments.

A really decisive advance in mechanical interrupters was made in the introduction of the "Mercury" form of interrupters, and still undergoing a gradual improvement this device has taken a firm place at the head of all varieties save the "electrolytic." Mercury interrupters developed along three types—the vibrating, oscillating, and rotary—and in Europe where they were used with minor pressures,

gave greater speed, and smoother and more continuous working than any previous break with heavy primary currents; but, wherever the street current was chiefly used, all the interrupters so far mentioned were either radically deficient or had not yet been constructed to suit the higher pressures.

Then, like a revelation, in 1899, came the Wehnelt break from Charlottenburg, showing how immensely the output of a coil might be increased and intensity of bombardment gained with coils no larger and currents no higher than had been used before. The curious simplicity and astonishing method of the electrolytic device of Wehnelt not only led others to modify the type and aim to develop greater endurance and regularity while removing some of the obvious drawbacks of the initial models, but almost at once suggested the adaptation of mercury interrupters to more rapid rates and heavier discharges and pressures. The "jet" principle of action was the result, and has developed a break which can be adjusted to all frequencies from 100 to 50,000 periods per minute, is almost noiseless, compact in design, extremely durable, of flexible regulation, and applicable to any circuit up to 250 volts. It is a break of very high efficiency at the present time, and unless the electrolytic interrupter can be perfected the mercury jet will bid fair to hold first place among these essential arms of the coil. As 1902 opens still newer mercury types give higher efficiency still, and promise to lead the field in practical work.

A third factor which must bear a mutual relation to the current-generator is the tube. Particular statements about coils will not appear to be true *unless tubes are suited to the character of the bombardment from the coil*, but bearing this in mind it may be stated as a good general rule that a very long spark is not alone the measure of efficiency, and ordinary workers do not require apparatus giving maximum sparks of twenty, twenty-four, or more inches. Do not trust to the mere *length* of any discharge. Look at it closely and from quite another stand-point. With the eye study its degree of "fatness," for a lean spark of even two, or three, *feet* is not the ideal for X-ray work. It must be *relatively thick*. What would be "thick" for a six-inch discharge would be thin for an eighteen-inch discharge, but a thick bombardment from a medium coil will work a good tube better than a thin bombardment from a coil of much higher rating in mere length of spark.

With the ear listen to the discharge and note if it be sharp, tense, detonating, with evidence in it of volume, pressure, and disruption, which the ear can detect better than any of the other senses. The driving force and fatness of a high-efficiency bombardment, once heard by a novice ear, can never be mistaken afterward for the light sputtering of a thin volley. Note also if the discharge is *smooth and even* in regularity; or if it is mixed and jerky. The bombardment must not only be intense and full of quantity, but it must be mechanically regular and sustained.

The longer the spark-rating of the coil the higher resistances in tubes it will drive the current through, hence larger coils will excite tubes that have passed beyond four, six, and eight-inch pressures. But the fluorescing efficiency in the X-ray output of a tube increases in proportion to *the quantity of current in the bombardment,* and with high voltages a high amperage becomes rapidly heating at the point of high resistance. Therefore anodes must be made to carry extra heat if they are to be used with what are called "heavy" currents, and, owing to a combination of practical reasons, including the higher cost, we need not seek extremes of voltage and quantity, but rather a satisfactory working *medium* which will serve all ordinary purposes in medical and surgical employment.

It may therefore be held that twelve to fifteen inches is long enough for a spark rating if the volume is thick in proportion and if the interrupter is right and the tube suited. With such an apparatus a fair degree of skill will enable the operator to meet nearly all emergencies. The main aid to fine work will not be a larger coil, but selected and up-to-date accessory devices which do so much to bring out the fullest measure of capacity in the foundation part of the equipment.

Various operators have suggested modifications of the Wehnelt break. Holding forth as it does the most alluring promises of X-radiance beyond any otherwise obtainable, it has been a veritable tantalus in actual work. Men read that it has been robbed of its smell; that it has been made permanent in durability; that it no longer chokes; that it will work with the alternating as well as the direct current; that it has been made readily controllable; that it will suit any tube; and living witnesses find on test that it breaks all these promises and needs yet further improvement before it can take its place among the reliable accessories of the X-ray coil.

Still, it is true that ingenious individual experimenters seem to accomplish what the majority fail of doing. Thus, a writer referring to European progress in radiography recently stated: "Somehow, by using large volumes of electrolyte (fifteen quarts), and by suiting the self-induction of the coil primary to the working pressure, our continental friends appear to obtain more satisfactory conditions with this

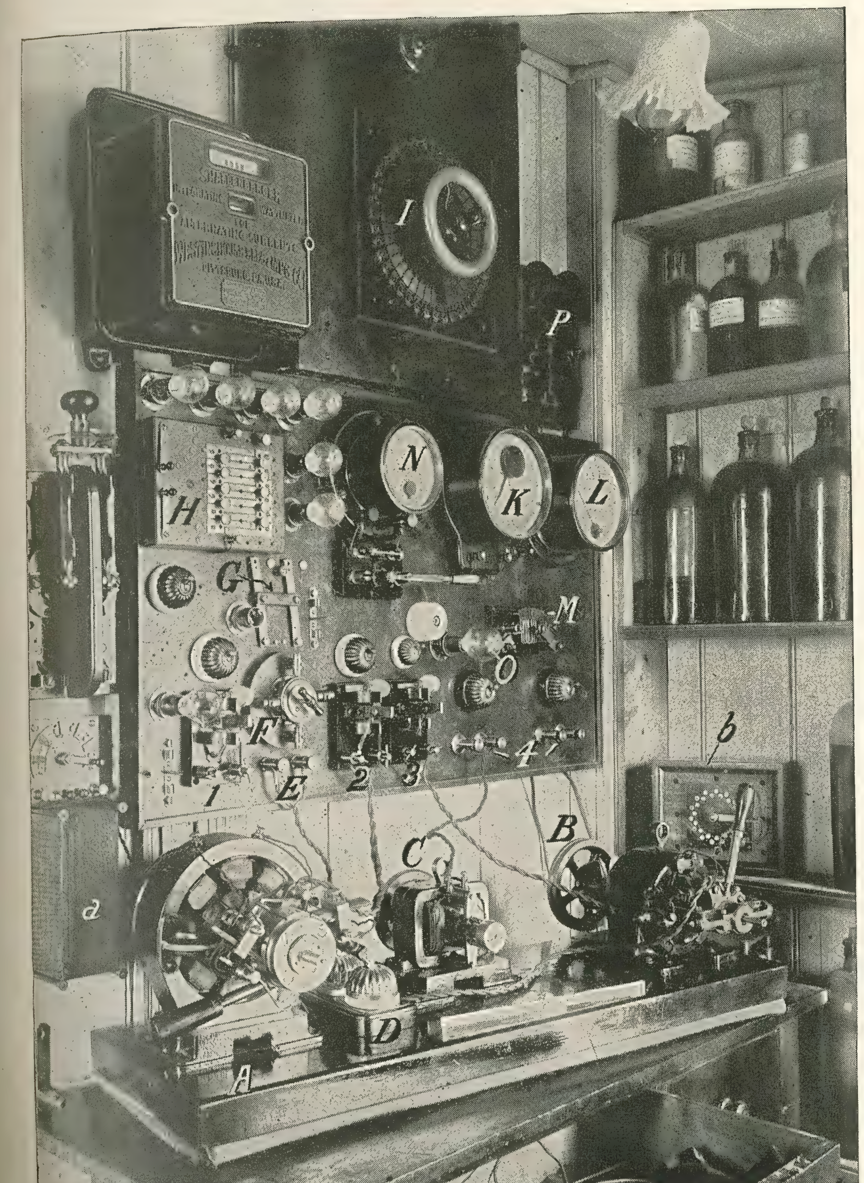
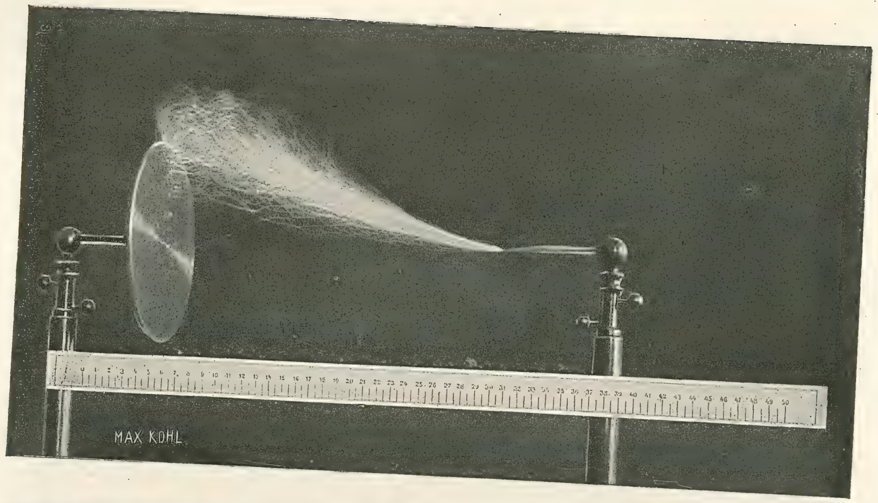


PLATE 1.—Illustrating the switchboard and rectifying device of an English Surgeon who operates a continuous-current coil with an alternating-current supply from the street circuit. (Rebman, Ltd.)

No general illustrations of coils, Static machines and X-ray apparatus will be attempted in this book, as they properly belong in the catalogues of manufacturers.

PLATE 2.—Photograph of Spark Discharge on Film. This plate illustrates the effect of an electric discharge of accidental occurrence just prior to connecting a tube in circuit. The photographic plate was on the base of the tube-holder: the patient's hands were on the plate, and the wires from a ten-inch coil were supported by a high stand with their free ends resting on the table within an inch or two of the plate. The current was accidentally turned on for a few seconds while preparing for the exposure. The negative wire was at the lady's right hand. She felt a shock, but there was neither spark nor disruptive discharge seen. No trace of the current could be detected afterward on the plate-envelope. The print shows that the spark reaching the film was a small discharge. Beautiful studies of these tree-fern-like tracings on sensitive films may be made at will by any operator, and it does not require much of a current to fill the face of an 8 x 10 plate with wonderful markings. Each pole makes its own peculiar tracing, and when both discharges meet the front and back of the plate at the same time a merging of effects results which can easily be identified by one familiar with these pictures. (Rebman, Ltd.)

PLATE 3.—Positive Phase of Electric Energy. Action upon the film of a single positive spray discharge from a high potential coil. This fern-like picture of a power in scientific medicine which the profession is only just awakening to study, but which it has happily become a badge of ignorance to deprecate, is reduced from a magnificent photograph 18 by 22 inches in size. It therefore does faint justice to the beautiful original. It is one of a remarkable series of fifty photographs of different electrical discharges, all 18 by 22 inches, made by Mr. Kinraide, of Boston, in experiments with the Kinraide coil. Having seen them all, the author has the greatest regret that it is impossible to present them here in unreduced impressiveness. Without question they furnish the most striking, unique, and magnificent record of electrical discharges ever made. They would have astonished Faraday beyond words.



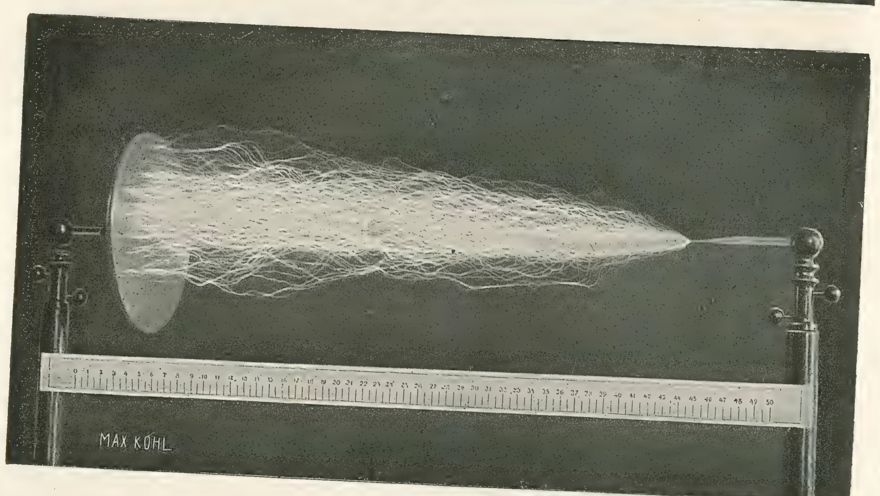


PLATE 4.—These plates illustrate the brush discharge from a sixteen-inch coil with the Wehnelt electrolytic interrupter. Note the difference between the fat stream and the ordinary spark of mechanical breaks. The parallel scale shows the great reduction from the original.

break than has been our experience, for one authority, in strongly recommending the use of the Wehnelt, lays stress upon its quality of *being practically permanent in working, and requiring no attention and no cleaning or repairs for years*, so that it may be placed in a distant room under a flue in order to eliminate its objectionable noise and gases."

In this country it is at present fair to say that for use with the continuous current and with small alternating currents the best types of electrolytic breaks have been improved to a reasonable degree of satisfaction. With large alternating currents most of them break down, but having confidence in human inventiveness we may consider that in due time the worst of the difficulties will be overcome, and that in this form of break will be found the cheapest, simplest, and most direct road to high-efficiency interruption.

Tubes for use with electrolytic breaks must have a rather high vacuum. They also require great heat-resisting qualities in the anode. In early use ordinary anodes were burnt out in a few seconds or minutes. Special and heavy construction now gives durable tubes for these interrupters. As there are many designs in the market, get full operating instructions from the seller for the one purchased. With a perfect electrolytic break a medium coil nearly equals the efficiency of a very large coil. In fact new possibilities are opened up to designers of coils by recent interrupters, which give fresh impulse to the improvement of X-ray apparatus. Changes from old models aim at wire-saving and simplicity with higher efficiency. New accessories can be attached to old coils and thus earlier buyers can keep pace with improvements at moderate cost.

Static Machines for X-ray Work.—If a Static machine is decided on it should be one giving *fatness of current*, and not mere length of spark. This can only be obtained by applying the same principle which gives large amperage to cell-currents, to-wit: the arrangement of many plates (or cells) in "parallel." Diameter of revolving plates gives a great part of the *voltage* of the current. Each added pair of plates in parallel adds to the richness of the current in *quantity*, and this factor, which is so vital to X-ray work, cannot be imparted by speed, size of plates, or any other feature of the Static machine. My own idea of the efficiency of a large current, as compared with a small current, has been obtained from a year and a half of experience with a machine having thirty-two plates (sixteen revolving) thirty inches in diameter. Having begun years ago with a four-plate machine, then a six plate, then an eight plate, then a ten plate, as experience and improved results led to a desire for a richer and thicker current a jump was made to my present apparatus. Nothing that can be put into words can convey a realistic idea of the vastly greater *working-capacity of a large Static current* over the small currents in general use obtained from all machines of all makes and types having only twenty plates (ten revolving) of thirty inches diameter, and sizes less than these.

As we shall at a convenient time re-write and bring up to date our now historic and out-of-print "Manual of Static Electricity in X-Ray and Therapeutic Uses," we deem it needless to repeat here our well-known views regarding the value of this electrical apparatus. When our first volume appeared there were two established manufacturers of Static machines in this country, with a recently added third; that there are now more than twenty in the same field is sufficient evidence that our teachings have been accepted.

Trouble-Hunting.—When an X-ray tube does not light up, what is the matter? Where is the trouble, and how can the novice trace it? When found, how can it be repaired? These are questions of magnified interest to the beginner, and at times even the expert finds in them something to engage his attention.

As there are now in America alone more than thirty different makes of X-ray apparatus, no two of which are alike in all respects, it follows that directions cannot be written *secundum artem* to fit each detail of different construction. But the lamp of experience soon endows the expert with an intuition that emulates clairvoyance, and for the novice certain principles can be laid down that will put trouble-hunting on a practical basis.

In all electrical installations the art of finding and correcting faults in the circuit needs cultivating, for *perfection* and *permanence* are two words not yet incorporated into the lexicon of electrical apparatus. But interruptions of *function* in X-ray apparatus do not always mean accident and injury, nor expensive repairs. On the contrary, with improved modern equipment and reasonable care an injurious accident will very seldom happen, and most of the operators' trouble-hunting will relate to slight faults in the working efficiency of some part that is not properly *adjusted.*

Until skill and acquired perception lead instinctively to the seat of fault make it a rule to trace the current from its origin to the break.

1. Test the source of current supply. Does the generator *generate?* Is there current at the primary poles of the coil or static machine? If not, then the trouble is behind them. But where? Examine the wires and contacts between the terminals and the cells or socket. The basic principle that all wires must be intact and all contacts sound applies equally to a primary or storage battery and to the street current. Inspect them all.

If a fuse has blown out or if cells are run down, a short-circuit test at the primary contacts will show no current present. This soon leads to the exact location of the fault.

2. If current comes up to the coil but fails to develop a full dosage then test the condition of the coil in the following manner: nearly close the spark-rods and switch in the current; draw the rods apart and ascertain the maximum spark-gap; if too short and thin examine all connections and especially the interrupting device. The integrity, clean condition, and adjustment of the interrupter must be one of the first concerns of the operator, and this principle applies to all the types in the market. The coil itself is a passive mass and may be sound, well wound, and perfectly insulated in every part, but the vital centre of activity, which has all the merits of the coil at its mercy, is the interrupter. It must not only be in working order, but it must be regulated for the work in hand. Look at it and test its action before seeking trouble in the coil itself.

So skilled does the operator soon become in locating trifling disarrangements in his apparatus that a rapid glance over contacts, interrupter, and the accessories of rheostat, metres, and such switches as exist in the given outfit will detect and correct the trouble almost in a moment. If there is a real break-down that needs the aid of the repair shop, the beginner will do well not to be too hasty in shipping the apparatus to the maker. First get the invaluable experience of trying to fix it yourself. There is a lot of instruction in such an effort. If it fails and a workman can be called in let him show and explain to you all he does, and next time it may be needed the knowledge gained will be very useful. Trips to the factory are seldom required for high-grade apparatus which embodies modern improvements, and *the best thing to do with poor apparatus is to trade it off and buy better.*

3. If the source of current supply is all right, and the coil and its connections test up without fault, then the trouble may be looked for beyond the terminals, *i.e.*, in the connections of the tube or in the tube itself. If the current is under proper control a contrary action of external wires, contacts, and tube is soon traced.

For the instruction and encouragement of many workers in hospital and private practice, who still employ apparatus purchased in the first or second year of Roentgen's discovery, we think it valuable to cite some remarks made by an expert who himself adheres to such an apparatus.

"If there be any special merit in much of my work, I believe it is due not to new discoveries, but to the consistent adherence to one or two features, especially antiquated. I do not wish to be understood as implying that nothing which is new is good; but rather that much which is old is also excellent. Visitors to my experimenting room, who are at all familiar with modern X-ray apparatus, nearly all exclaim at the very slow speed at which the interrupter is run, and wonder that a form of break so ancient is adhered to. When pictures are shown with exposures varying from three seconds for a hand and wrist to a couple of minutes for a thorax; and when they see a screen brightly illuminated ten feet from the tube, the surprise is none the less marked, but along different lines. There is no doubt that slow interruptions are inconvenient for fluoroscopic work, but they are very efficient when pictures are required.

"Difficulty is often met with in adjusting the interrupter for different rates on account of the sparking which results. In this case the capacity of the condenser is probably not suited to the set of conditions that must be met. In other words, the time of a complete cycle of operations, and *the ratio in which this period is divided between closed and open circuit in the primary*, is of great importance, and is related to the self-induction of the coil and the capacity of the condenser intended to take up this extra current. If the capacity is too small the condenser will be only partially affected, and sparking will result at the break. It is probable that the ordinary commercial coil would be much more efficient if its condenser were several times larger than usually made. I am told by makers that on the commercial X-ray coils, the capacity of the condenser varies from five to fifteen micro-farads. A hasty measurement of my own shows its capacity to be about thirty-five micro-farads.

"Adjustment should be made so that the actual interruption of the primary current shall be as sudden as possible. This results in a rapid variation in the magnetic flux through the iron core, which induces in the secondary a rapidly increasing electromotive force. This act of breaking the primary, however, produces a self-induction in the coil, which in itself tends to retard the suddenness of the break by causing an arc between the points as they recede from each other. If, however, a condenser of large capacity be connected around the break the extra current will flow into that. The condenser evidently must be of capacity sufficient to absorb all the charge that would otherwise tend to jump between the contact points. But a very important part of the phenomenon is yet to follow. The best iron core will not alone lose its magnetism except after a period of time which is considerable when compared with intervals of the minute order which we are contemplating. To effect this necessary result the condenser at once discharges back through the circuit and demagnetizes the core very rapidly, thereby inducing an enormous electromotive force in the secondary coil current.

"If a coil with an insufficient condenser be operated slowly, it sparks badly at the break. If the speed be increased until the sparking is minimum, it is so because the time of 'make' has been too short to allow the direct current to obtain a maximum. The extra current due to self-induction is therefore less, and the small condenser can take care of it. Obviously, under these conditions, the coil is not operating with maximum output.

"The time of 'make,' when the primary is closed, ought to be just long enough to enable the current to reach its maximum value; the time required depending on the self-induction of the coil as well as on its resistance. The time of break when the circuit is open must be long enough to enable the condenser to be charged and discharged. If the 'make' follows the break too soon the direct current will interfere with the discharge of the condenser.

"Furthermore, it must be remembered that the coil with all its attachments may be in perfect adjustment to be operated as an *inductorium*, pouring streams of full-length sparks between the terminals of its secondary, and yet not be in the best adjustment for *operating an X-ray tube*. The mutual induction between the two coils is obviously not the same in the two cases, and hence the conditions are somewhat modified."

CHAPTER VII

CROOKES TUBES

Present Classes of Tubes. The "Best Tube." Gold Medal Tube. Author's "Static Tube." Hard and Soft Tubes. Punctures. Do X-Ray Tubes Explode? Connecting Wires for Tubes.

More inquiries have reached me during the past five years on the subject of tubes than on any other detail of X-ray work, showing that the average practitioner finds his chief problem the one of obtaining satisfactory Crookes' tubes. In this chapter we shall discuss the more practical side of the subject as it relates to the buyer and user, rather than the maker and experimentalist.

Tubes may be broadly placed in the following classes:

1. Plain two-terminal tubes.
2. Plain three-terminal tubes.
3. Adjustable tubes.
4. Self-regulating tubes.
5. Water-cooled tubes.

As current-generators have delivered heavier and still heavier bombardments upon the anode, and as new types of interrupters have thrown into the focus a greater and greater quantity of heat, it has been a constant struggle for the tube-maker to keep pace with the coil. In the Spring of 1896 the anode was as thin as tissue-paper. Soon tubes were made larger, terminals were farther apart, and the platinum was thickened to a plate. Then a backing to absorb the excess of heat was added by some. Then some of the heat was shunted to a second electrode. In theory a flow of water upon the target would cool it and remove the cause of complaint, and, though expensive, it was tried. Many modifications in the construction of tubes have been made to adapt them to modern heavy discharges, and the best results have been obtained by adapting the tube as a whole to the current used with it, and not by any special single device.

The plain, well-made two-terminal tube renders good average service with a minimum of trouble if it is suited to the apparatus and

the operator knows how to manage it. Such a tube often does work of the highest class and lasts indefinitely; but men of less practice may get only ordinary results with similar tubes, or may even complain that they are very poor. The personal equation counts for more than thirty per cent. of the efficiency of any X-ray apparatus. It may at first count for more than half; for when skill is being acquired the process is more rapid with some men than with others and goes farther in some cases than in others. Therefore, the exact efficiency of a tube *per se* is not a fixed quantity but varies according to the man behind the apparatus.

The first "adjustable" tubes had no real advantage over plain tubes, for while resistance could be lowered when it rose to excess it did not stay down. In from one to ten minutes after releasing into the bulb the chemical atoms which increased the conductivity between the electrodes and made the gap less resisting, the atoms took on polarity and ranged themselves in alliance with those already collected at each electrode. By a new discharge of volatilized chemical the resistance could be again reduced, but in practice it was found that a tube which needed this repeated attention was not made satisfactory by it, and that a tube which worked finely seemed to do so quite independent of the "adjustable" feature of its construction.

The next step was the addition of a device to keep the resistance down to a point of definite adjustment without frequent attention from the operator. This made the tube "self-regulating." The first such tubes were very complicated and frail. Very recent improvements have seemed to mark an advance. The potash salt is sealed in a terminal connected with a spark-gap shunt-current from the main circuit. When the resistance varies the current follows the line of least resistance. If this is the line of the shunt-current the reducing salt is acted on till the path through the vacuum is opened, when the shunt automatically closes out. The balance is finely held. The adjustable resistance of the shunt circuit controls the resistance of the main circuit, and the self-regulation of the tube follows the preliminary regulation of the dosage desired by the operator.

Very satisfactory steadiness seems to be maintained in action, and a not unimportant feature is the fact that no outside spark is likely to jump through the glass and puncture such a tube, because the spark finds itself shunted through the regulator where it is harmless. This claim of the makers has been substantiated in such tests as the author has so far made with these new designs.

With means of regulating the dosage of current (and this is especially true with a complete Static machine equipment and training), the plain two-terminal tube of medium vacuum can be varied at will, through all degrees of radiance, from a very small low X-ray output up to a profuse, brilliant, penetrating, and rich light. A single tube may thus serve a variety of purposes and cover all the work for which some claim that half a dozen tubes would be necessary. This flexible adjustability of X-ray dosage with an ordinary tube of suitable initial vacuum must be known to several thousand physicians and surgeons, for the author has been teaching it since 1896. It seems, however, to have escaped the notice of a number of writers. The object of "vacuum regulators" and ingenious accessory devices is nearly the same, but seeks to regulate the vacuum without regulating the current. Both methods are useful in practice.

The Best Tube.—Who makes the best tubes? Which is the best tube? Where can the surgeon get good tubes? During the past four years these questions have been asked by thousands of beginners. The answer cannot be a categorical one. The tube is not an independent device. Its working efficiency depends in part on factors outside itself, and just as a chain can be no stronger than its weakest link, an X-ray tube can be no better than the chain of working conditions. This is not sufficiently understood, even by men of several years' experience, for very few operators make a serious study of skilled *manipulation of tubes*. We may, however, say, first get good apparatus, next get skill in manipulation; then all tubes will fall readily into one of three classes:

Class 1.—Tubes you can make work at once with excellent satisfaction.

Class 2.—Tubes that a brief test will show can be made to work with a little indicated manipulation.

Class 3.—Tubes to reject at once for any of a dozen reasons that tests will demonstrate. Do not buy too "high" tubes.

The adaptation of a tube to a particular apparatus is not quite as narrow as the adaptation of a shoe to a foot or a glove to the hand, but within reasonable limits the tube must suit the electrical discharges, or the electrical discharges must be regulated to suit the tube. If neither of these things can be done by a given operator he had better reject that particular tube and select another which will work with his apparatus.

In order to lessen uncertainty in dealing with the problem of satisfactory tubes the student should first study to acquire the following information:

1. A knowledge of proper electrical dosage for individual tubes.
2. A knowledge of all the varieties of manipulation that tubes require. The technique required for the type of tube in hand.

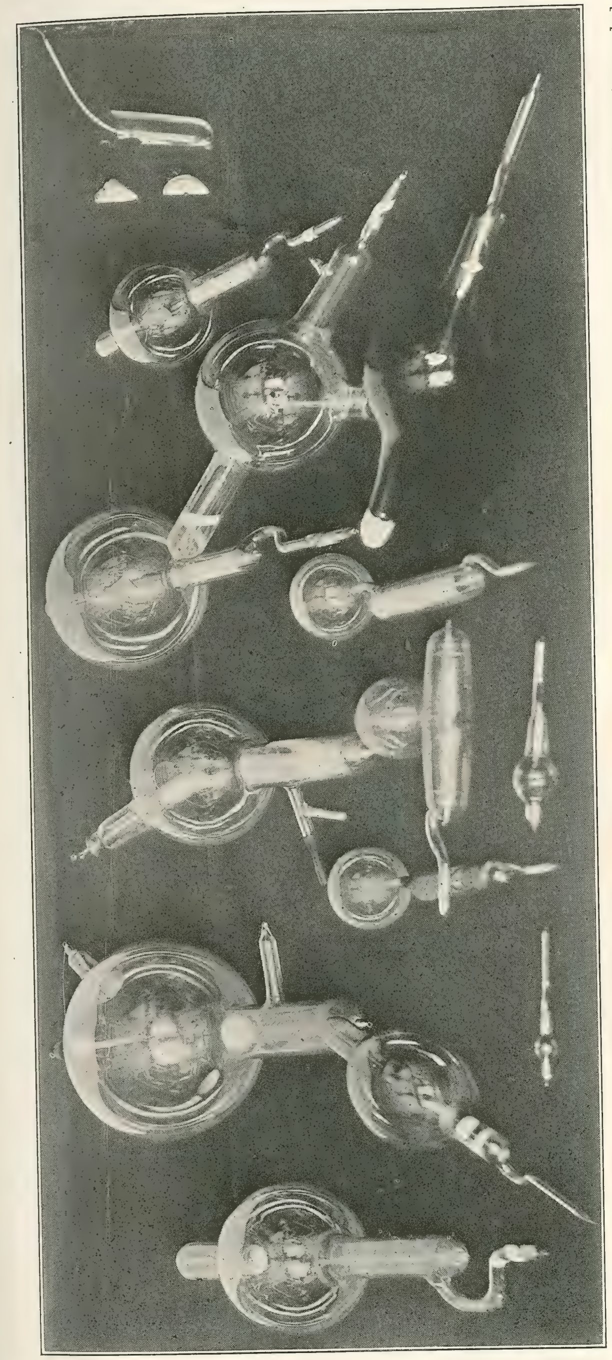


PLATE 5.—Showing Various Tubes from the Author's Collection. The large tubes are all modern. One just at left of the centre is a water-cooled tube. At the right-hand corner is an old tube partly coated with black varnish. Near the left corner is the smallest X-ray tube ever made. I have safely excited it with a large 20-plate Static machine. Its bulb is half an inch in diameter. At its right is a fine tube with a bulb one inch in diameter. It has worked well with a large Static machine. The tube second in central line and just above this was the first double-focus tube made in this country. The small tubes were made solely for the author's tests. In the upper right corner are the fragments of the exploded tube mentioned in this chapter. Note the bend in the stiff metal rod and the folding of the electrodes by the force of compression.

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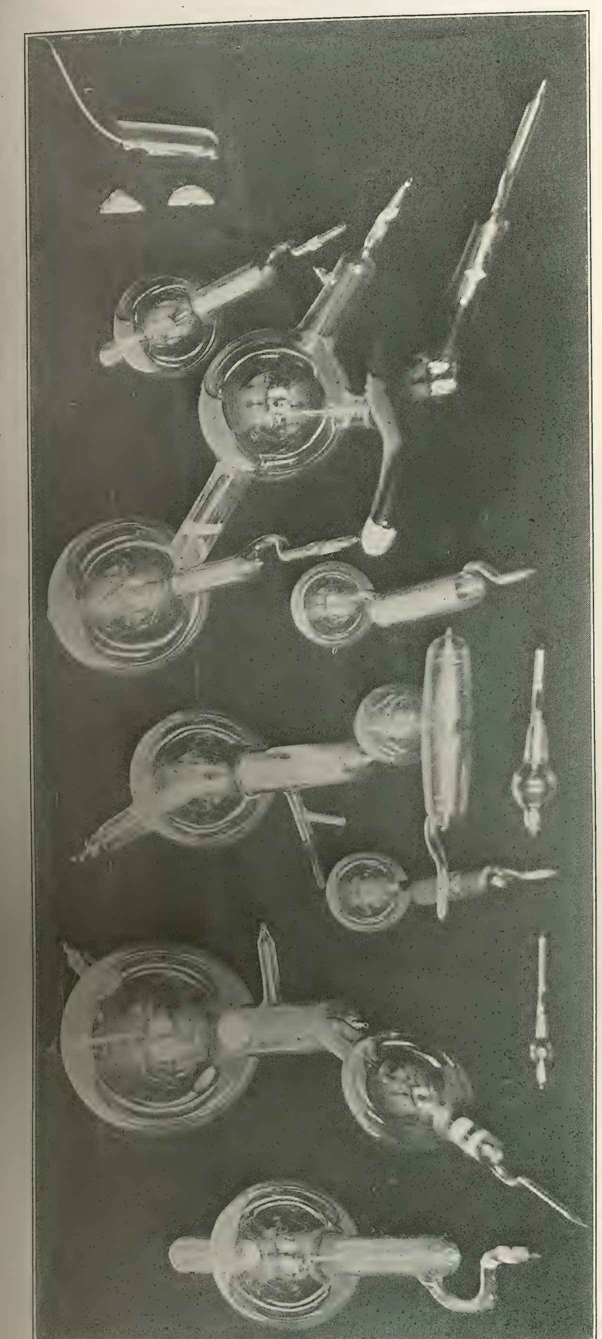

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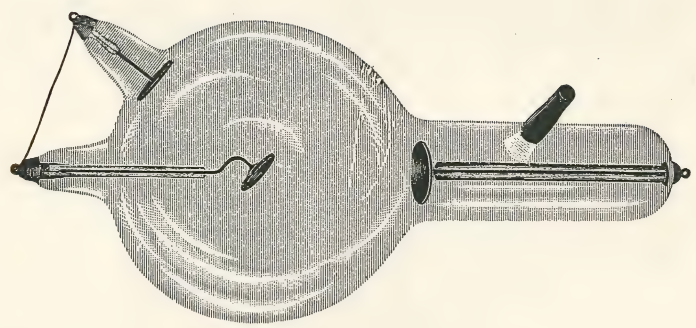


PLATE 6.—The "Gold Medal" Tube. The plain three-electrode tube, winner of the Gold Medal Prize. Of the 28 competitors, 8 were American makers, 5 English, and 15 German. The Gold Medal tube is sold in this country by several importers, and is also made with a self-adjusting auxiliary.

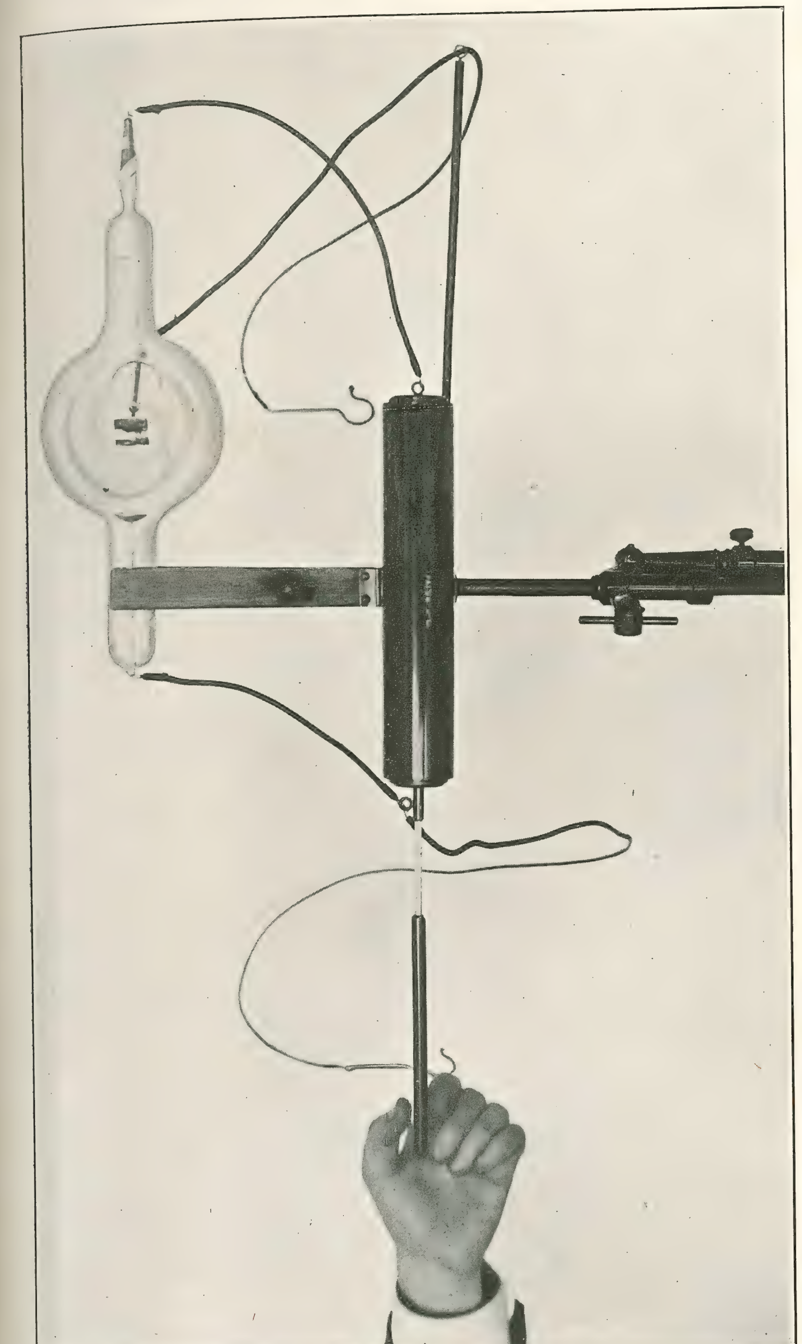


PLATE 7.—The Bario-Vacuum Company Automatic Resistance Regulator. Set up the tube and Regulator as shown in this Instruction Plate. Do not reverse the poles. Attach the left hook to negative and right hook to positive pole of current. With Static machine use interrupter on positive pole. Start current with small spark-gap and rod of regulator pushed in. Develop the desired amount of current and gradually pull out the rod till the radiance is regulated to suit. During continuous use modify the position of rod as needed to keep the action steady.

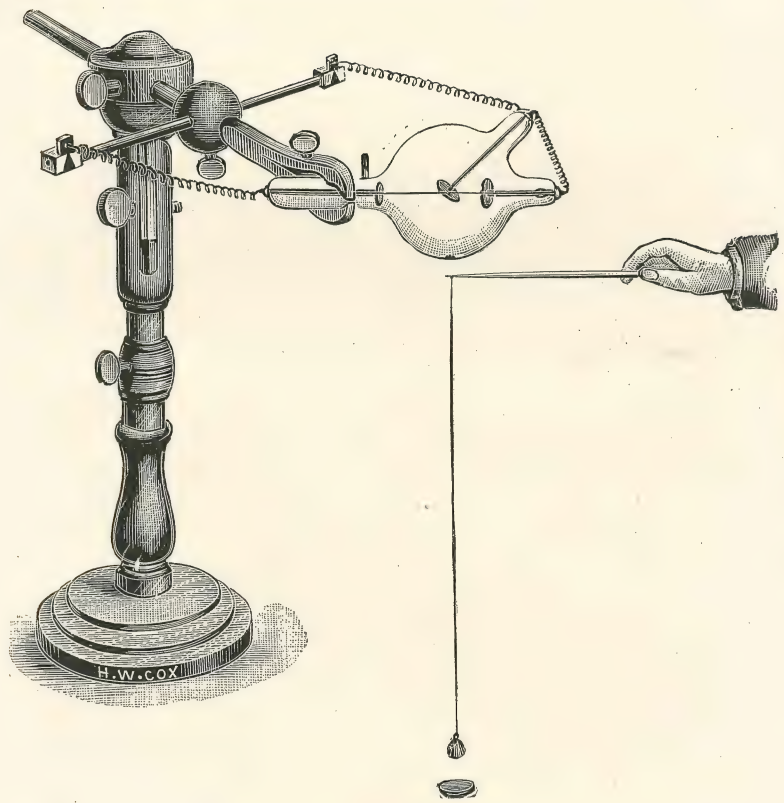


PLATE 8.—This figure illustrates the proper method of dropping a plumb line from the focus of the tube to the centre of the plate or part to be examined in the axis of the rays. Take a thin stick of wood whittled to a point—use no metal—turn around it the silk thread to which the plummet is attached, and employ it as shown in the cut. Care must be used to drop the line from the precise spot of the lower wall of the tube through which the axis of the central ray passes. It will be noted that a line can be dropped only in the perpendicular, while the author's Position Finder is equally accurate and available in all directions and planes. With it a tube and plate can be squared almost instantly in any position required by the case. (Rebman, Ltd.)

3. The ability to detect at a glance during tests all faults of working, and correct them.

4. A knowledge of what actually represents the maximum capacity of a given tube.

5. A knowledge of both the limitations and possibilities of X-ray effects.

6. A knowledge of tests by which to demonstrate the causes of faults anywhere in the circuit with the tube.

It is very easy to know how to tell a poor tube from a good one by a moment's examination and test, but unless the operator has this elementary knowledge no one can answer for him the question as to which is the best tube. First secure the above knowledge by rudimentary study of working principles, and you can answer the question yourself.

Good tubes are becoming much more common now than formerly, and each year will see some improvement. The gold-medal prize offered for a fine tube, in 1901, gave an impetus to manufacture which will be far-reaching.

Gold Medal Tube.—To encourage the production of a satisfactory tube the President of the Roentgen Society, of London, offered a gold medal for the best practical X-ray tube for both photographic and screen work. The conditions were as follows:

1. The tubes are to be exhausted for testing upon a ten-inch spark coil working at eight-inch alternative spark-gap.
2. The tube must be well made and properly capped.
3. The price of the tube will be a factor in the adjudication.
4. The price submitted shall be that at which similar tubes shall be obtainable through usual retail sources.
5. The tube will be tested and marked for—
   (*a*) Penetration.
   (*b*) Photographic effect.
   (*c*) Screen work.

A jury of twelve of the most eminent and scientific men in this field of interest in Europe, including Sir William Crookes and Professor Roentgen, was chosen to test all tubes submitted. They devoted more than a month to the decision, and announced a verdict about July 1, 1901. There can be no doubt of the thoroughness of the tests made nor of the entire ability of the men who made them. No series of tubes was ever before submitted to such an ordeal, and the merit of the selected design must have been unmistakable. The winner of the gold medal was the design of Mr. C. H. F. Müller, of Germany, entered by an English firm. Twenty-eight entries were received for the competition, some of which were excellent as to glass-blowing, but seventy-five per cent. failed to meet the *definition tests* that were the important requirement of the donor. Definition, photographic effect, penetration, and moderation in price were the chief considerations, and the striking lack of the first quality (without which all others are useless) compelled the committee to draw the attention of manufacturers generally to this defect. It is a defect that lessens the value of nine-tenths of the X-ray examinations made in America or Europe, and should be remedied before any other feature of tube construction.

Author's "Static Tube."—Since the wide-spread employment and recognized efficiency of the larger Static machines in X-ray work, the main interest of this particular tube is historical.

Throughout the early half of 1896, Static machines were tried and rejected as unsuited to the best X-ray work. About July, 1896, the author concluded that the dissatisfaction arose mainly from the fact that makers did not adapt the vacuum of tubes then in the market to the peculiar character of the static current, which was then used without interrupters. I do not now speak of small machines which required Leyden jars for operation.

During several months experiments were made with the co-operation of four different makers, and the result was the standardization of the character of tube required for static work, the lifting of the previously condemned Static machine into the first rank of X-ray apparatus, and the publication of the author's epoch-marking article on "Crookes' Tubes and Static Machines," which appeared in *The Medical Record*, February 6, 1897. Makers then began to construct and supply what has been known for the past five years as the "Monell Static Tube." It was always a plain, two-terminal tube, of practical utility, possessing good ordinary every-day qualities of action; extremely reliable, strong, seldom puncturing, and, on the whole, giving very general satisfaction to all purchasers who had skill enough in operative technics.

Several hundred of these tubes passed through my hands, in 1897-98, for personal tests of quality before being sold. The average was excellent. Many were equal to the best tubes of any type. Very few deserved rejection. A single instance, however, may illustrate that satisfaction with tubes depends somewhat on how they are operated. A surgeon came to me for instruction. He was delighted with *my* tubes; said he had two similar ones in his office for a year; could do nothing with one, and could only make the other flicker without lighting up. He was asked to telegraph for them. He opened

the box himself, handled the tubes without my touching them in any way, connected up one, and managed it as he had been instructed. It worked beautifully. After ten minutes of fine action he got out the second tube. For about two consecutive hours he rejoicingly operated this tube at very high efficiency without stopping it a moment. He made all sorts of tests with it and was so enraptured at finding that what he had regarded as useless for more than a year were in reality a couple of choice "prizes" that he would not again trust them to the express, but went out and procured a special case in order to carry them home in his own hand. The episode is instructive.

With the introduction of interrupters and general improvements in regulating devices for both currents and tubes, the importance of a great deal of pioneer work has passed. Many varieties of modern tubes will now work well with Static machines, and the adjustment of vacuum is far better understood by makers to-day than it was when the first edition of my now historical "Manual of Static Electricity in X-Ray and Therapeutic Uses" went to press. Many arguments of 1897 are now obsolete. The three-terminal tube and regulating devices have succeeded two-terminal and plain tubes in popular favor.

Hard and Soft Tubes.—During the past year or more it has become common to write of tubes as hard or soft instead of high or low resistance, as formerly. These terms were translated from a paper written by Professor Roentgen himself. I do not know what the originals were, but the translator who turned them into the English *hard* and *soft* did not improve on *high* and *low*, which had become familiar. The words are indefinite, unscientific, and, in reality, are so meaningless that confusion has been added to the subject of tubes by the efforts of different writers to describe exactly what sort of a tube is a hard tube and what sort of a tube is a soft tube. A review of a large number of articles discloses a surprising difference of opinion among writers as to the exact shadings of quality which place a tube under one head or the other, and some seem able to discriminate so finely that we cannot follow them. The common understanding may be that a tube of low resistance is a "soft" tube and a tube with high resistance is a "hard" tube, but the literature of experts show that it is not all so simple as this.

Resistances of tubes are relative to the driving force of the current, and a resistance which would be high for a small current would obviously be insignificantly low for the voltage of a twenty-inch spark. In the interests of practical simplicity, the words hard and soft will not be used by the author. One operator may think he knows what he means when he uses them, but another operator may hold quite a different interpretation of the words, and in the absence of a common agreement they have no value.

Some think hard tubes give off X-rays of great "wave length," while soft tubes give off rays of short "wave length." Some assume that the rays of a soft tube are "absorbed" by the skin, while the rays of a hard tube affect the deeper tissues only. The dogmatic theories met with in current literature will largely fall to the ground in practice, and taking any dozen tubes and running the dosage of exciting current up and down (as can easily be done), it would be impossible to find two men out of ten who would agree in saying how hard or soft they were. Obviously the intent is to indicate an idea of the penetration of the rays, but these vary with any given tube according to the energy of the bombardment which excites it, and *every tube that will do good work at all can be made to do a wide variety of work.* Therefore, the accurate and practical measure of penetration is the author's Gauge described in this book. It will measure the exact penetration employed at any time, with any tube, with any degree of activity, and with any wattage of current. It is commended to the profession as a scientific substitute for guess-work.

In lieu of the gauge measurement, however, it is much better to record and report the resistance of the parallel spark-gap rather than to refer to tubes indefinitely as either hard or soft, or high or low.

A writer in a recent X-ray journal says: "All operators have to admit that no accurate and standard method for determining the quality of the X-ray has yet been devised," but if by "quality" is meant the working factors of the rays in penetration and defining power, then the author's gauge has long afforded an "accurate and standard method." A perusal of Chapter XX. and a personal test of the instrument will demonstrate the facts.

Punctures.—What is a puncture? Why does it occur? How can it be avoided? Can it be repaired? These and other questions occur to beginners. A tube may be *broken* in various ways, but a "puncture" is usually a very small, almost invisible, perforation through some thin part of the wall of the tube, and is caused by the passage of a fine spark between an external terminal wire and an internal electrode or supporting rod. To get from one to the other with the wall of the tube between them, it passes *through* the glass and punctures it.

It may occur upon either the positive or negative side of the tube, and the reason it occurs is a pressure of the electric-current in excess of the normal internal capacity of the tube, or the approach of an attracting conductor from the outside too near the internal

discharges. When the current goes easily through the tube punctures do not happen, because sparks do not then jump from either terminals or electrode. Certain methods of technique very rarely cause a puncture. Other methods contain an increased risk of puncture. Methods can be employed which will puncture tubes very rapidly. Experts aim to avoid them.

The glass in certain tubes is more liable to puncture than others. American tubes made of American glass seem less liable to puncture, even with sparking currents. Tubes made here or abroad of German glass, either may or may not puncture easily, but are difficult to repair. Tubes blown very thin in the bulb are not particularly subject to puncture, but extra thickness at the juncture of the bulb with the terminals is important. Bubbles and apparent flaws in the wall of the bulb do not seem to increase punctures. The internal structure may make some tubes more liable to puncture than others. Certain applications of tinfoil to reduce a high resistance increase the risk of puncture in proportion as the foil approaches the cathode or anode and in proportion to the sparking pressure of the bombardment.

Plain tubes made of American glass can usually be repaired, but whether they will be good as new or not will not appear until tested in use. Some repaired tubes never equal their first efficiency, while others are as good as ever. Complicated tubes may be difficult to repair. Certain fine German tubes imported to this country have shattered into a myriad pieces during attempts to repair a small puncture, and it is understood in the trade that repairs are at the risk of the owner.

While in certain cases a puncture will occur despite precautions, yet almost all punctures *are the result of increasing the sparking pressure of the electric-current beyond the internal capacity of the tube.* The higher the resistance of the tube, and the higher the pressure of current, the greater the tendency of the discharge to jump outside the tube rather than pass normally through it. A careful regulation of the dosage of the current to suit the working capacity of the individual tube will reduce the number of punctures to a minimum. A shunt-current regulator is to a great extent a preventive of punctures.

Life of X-ray Tubes.—Barring accidental breakage as distinguished from puncture the life of a tube has but two limitations, viz.: puncture by a spark and burning out by too heavy currents. Practically, however, the life of a tube is considered the period during which it works readily at a satisfactory efficiency.

During excessive use a given tube may temporarily alter its internal resistance and be non-usable for a time, but rest or manipulation will usually bring it back again to a working state.

Heavy electrical discharges generate intense heat at the site of high resistance, and thin anodes may quickly be burnt out by excessive currents. If a number of tubes are carefully used in rotation they recover a normal state during the interval of rest, and will very slowly reach the point of excessive resistance, which soon troubles the beginner who uses a single tube persistently.

Intrinsically, there does not seem to be any natural limit to the life of the tube. If accidents do not destroy it, it will last indefinitely. The author's most fragile tube, with an anode as thin as tissue paper, and an exceedingly thin bulb and handle, purchased in 1896, is still in perfect condition. On numerous occasions it has been kept in action continuously for one and two hours at a time without stopping the current an instant. It always works and gives no trouble. Another tube which had seen four years' service was as good as new when it was broken by being struck with a heavy gold ring on the finger of a student. In a laboratory in Philadelphia were two tubes, which had been on hand for about sixteen years, when Roentgen's discovery was announced. How long they had been in previous existence is not known. I have seen two superb radiographs made with these sixteen-year-old tubes early in 1896.

Physical damage, then, may be considered the only factor in shortening the life of a Crookes' tube. It is claimed that self-regulating tubes do not puncture, for the reason that the shunt-current of the regulating circuit absorbs what might otherwise develop into a spark discharge outside the tube, when the resistance or pressure of the main current becomes abnormal. Shunting off the extra spark protects the tube from puncture. Few of my tubes have punctured, and none in regular use.

Care of Tubes.—It is known that a lamp chimney will tend to crack with the heat if it is wet and cleaned in improper ways. Crude washing of the chimney and drying it with a swab on a metal rod will make the chimney crack when it is suddenly heated.

If a tube becomes finger-marked and dusty, do not wash it in water. Gently blow on it and carefully wipe it with soft tissue-paper. Make it a rule to avoid handling any part of the bulb. Always lift tubes by their *terminals.* Handle them *gently.* Do not screw or clamp them too tightly in a tube-holder. Clamp them with only just enough pressure to retain them in position. Do not allow any *metal* to touch the bulb of the tube. When not in use, keep all tubes wrapped in soft tissue-paper and put away in closed boxes, or in a

closed closet to protect them from both accident and dust. When getting out tubes for work, it is best to deposit each one separately on a softly covered table or shelf where they will not roll if disturbed. While tubes may be carefully laid on plates of glass or anything made of wood, yet it is best to avoid anything hard.

In connecting up a tube use care to avoid bending the platinum loops of the terminals. With too frequent bending they will finally break off. When operating with heavy coil currents the care given a tube must extend to watching the anode for signs of excessive heat and also the wall of the tube lest it soften and partly collapse from prolonged heat from an incandescent anode. The indications to reduce the current and cool off the tube must not be neglected. This care relates more to small tubes than to the larger ones now in general use, which do not yield easily to heat.

Do X-ray Tubes Explode?—Is there danger to either operator or patient if an explosion takes place? Readers have perhaps met an occasional alarming reference to these points. It is considered that a tube is subject to more violence *during its manufacture* than during actual use, and if it survive the processes of the maker it will endure use, barring accident. Minute punctures caused by stray sparks simply let down the vacuum and do not break the tube beyond the small perforation. An operator in Boston mentions that one of his tubes exploded while making an examination, and he "narrowly escaped injury to his eyes." On the other hand, an expert with exceptional opportunity stated in a discussion that he had handled over 5,000 tubes and had never known one to explode. Another remarked that in each of the *two* cases that had come to his notice some metallic object had touched the tube and caused the collapse.

Of the several hundred tubes used or tested by the author none "exploded," with one exception. On the evening of December 14, 1900, some observations were being made with seven physicians present in my office. A number of tubes had been got out and were scattered around in different places. Tubes are habitually laid upon tables, chairs, glass plates, and non-metallic surfaces without injury. Two large tubes were laid side by side on a chair. Each was wrapped in tissue-paper. Their walls were in contact with only the thickness of the paper between. Wishing to lay aside a long brass rod and forgetting in the darkness that tubes were under the loose tissue-paper, I laid the rod on the chair in such a way that it lightly touched one of the tubes. The report that followed was as loud as that of a large fire-cracker. The tube *collapsed,* rather than exploded; and this is what we should expect, since the external atmospheric pressure is immensely greater than the internal pressure. The tissue-paper was not blown outward. The adjacent tube was not injured in the least. On removing the covering we found the bulb of the tube shattered into minute fragments, the only pieces of glass of any size being the terminals. Evidence of sudden force of a collapsing nature was shown in the electrodes. Both the rods were twisted, and the anode and cathode were doubled upon themselves. The anode bore many small dents as if from pointed fragments of glass. The tissue-paper under the tube was sharply cut with a myriad of small slashes. This is the author's only personal knowledge of an "exploding" tube.

Connecting Wires.—Do not connect the tube to the terminals of electrical apparatus with conducting wires which are much longer than needed for the given distance. Do not let them sag near other objects. Have several pairs of wires of different lengths. Beautiful flexible cords with silk-covered insulation are supplied by dealers. Almost any copper wire, such as is used for ordinary batteries, will serve to connect tubes. The wire should not be too fine or too heavy. Extremely heavy insulation offers no advantage, because terminal contacts are usually uninsulated. With some forms of apparatus a wire stiff enough to retain the shape to which it is bent is preferable to a flexible cord.

It is essential to have these cords quite widely separated, and for this purpose a vulcanite or wood cross-bar *spreader* may be attached to the tube-holder. Those who have old holders without this device can easily make one. Get a wooden doweling rod three feet long and about five-sixteenths of an inch in diameter. Bore a hole of the same size through a convenient part of the tube-holder. Fix a screw-eye in each end of the wooden stick. For use insert the stick through the hole so that one-half will extend on each side of the tube, and parallel with it. Thread the wires from the electrical terminals through the screw-eyes of this rod before connecting them to the terminals of the Crookes' tube. The wires will then be kept widely apart during use. When disconnected the rod can be slipped out of the tube-holder or can be fastened in it permanently if desired. If a wire is carried from apparatus to an adjoining room or comes in contact with anything but air, it should be then heavily insulated so that none of the current will leak off. With a large static current the avoidance of leakage is a question of correct control of technic rather than direct insulation of wires.

CHAPTER VIII

POSTURING AND EXPOSING APPLIANCES

Tube-Holders. Plate-Holders. Film Protector. Examining Tables and Stands. Exposing Board. Body-Holder. Ophthalmic Head-Rest. Secondary Diffused Rays. How to Exclude Them. Metallic Backing to Plates. Diaphragm and Window. Lead Box for Sharpening Exposures.

Standard posturing appliances are essential to standard radiography. These mechanical appliances must cover means of holding the Crookes tube, the photographic plate, and the part (or the whole) of the patient. Without convenient devices for these purposes accurate and scientific radiography is out of the question. Certain accessory appliances also become important in special work, stereoscopic exposures, the rheotome method, and various localizing processes. Localizers are treated in another chapter, but tube-, plate-, and part-holders will be studied here. The first consideration is something to hold and "posture" the X-ray tube.

Tube-Holders.—Lack of a good tube-holder (or several of them) is one of the most annoying inconveniences of the beginner. It is the function of a proper tube-holder to *hold* the tube exactly where the operator needs to place it with reference to the patient, and to do it *conveniently* and with a total *absence of vibration* during work. The device is rare that will do this. Many of the small independent tube-holders in the market are lacking in some one or more of the qualities of a proper article. If they may serve in other ways they lack rigidity, and are so easily set shaking that they blur the definition of pictures which would otherwise be sharp and clear.

The basis of a tube-holder is a wooden clamp with a cork-lined grip mounted on a wooden post which may be one, two, or even three, feet long. If this is a long thin stick of springy wood it is not rigid enough for the purpose. No part of a tube-holder should be "springy." The tube must be as immovable as a camera during an exposure, and a holder that is easily affected by jarring impulses should not be used.

The primary clamp which holds the tube needs something to carry it to different positions, heights, angles, and relations to the patient, and for this purpose it is mounted on a jointed stand. Stands vary from mere toys to scientific and costly apparatus. The supply in the ready market is limited. Nearly all fine and special appliances are made only to order. They are divided into two classes—independent, and those attached to exposing tables. The independent tube-holder is portable and can be used with any exposing apparatus. It can stand on the floor or on the table near the patient. It can have a tall or short telescoping rod of metal or wood rising from a firm base; or it can be a frame, or upright closet, in which the tube is kept from dust and breakage when not in use.

The character of your X-ray work decides the kind of tube-holder you need. For a wide range of general work a universal holder is required, and as no one holder will be satisfying under all circumstances the expert will have a universal independent holder; and various special stands or an exposing couch with holder device attached.

Attached tube-holders are most convenient for difficult radiography. A bar supported on fixed uprights acts as a tube-carrier laterally or longitudinally along an X-ray examining table; or, a frame holding the photographic plate may have a side arm and runner to carry a tube-clamp. Arm-rests, leg-rests, knee-supports, head-rests for eye cases, standing-frames, adjustable-shelves, and so on up to full-length operating tables, all are made with attached tube-holders for adjusting the focus to any position under or over, behind or in front, of a patient, and at any desired angle. They possess the advantage over separate holders that, when once in position, any necessary shifting of the table carries with it the tube-fixture and avoids losing the focus adjustment, an important matter when much work is done.

For demonstration work and for the special needs of a practice limited to routine lines the operator will soon find out what suits him best, and can then have a tube-holder made according to his individual needs. One of the best combined stands and tube-holders for arm and leg work is made as follows: A stout upright rod of metal tubing stands on the floor on a firm base. On this post an adjustable collar clamps at any desired height and supports the device which carries the tube. The clutch grips the tube by a spring pressure instead of the usual set-screw. The tube can be turned on both its axes and shifted by movable arms to any situation needed. A small shelf can now be clamped on the post at any level to suit the part of the patient, arm, leg, etc. This shelf works on a ball-and-socket joint adapting it to all positions, and has holes one-inch apart over its

extent. Spring-clip pegs with straps fit these holes and permit strapping the part steadily in place during an exposure. The whole appliance has a wide range of utility and is one of the best the author has yet seen.

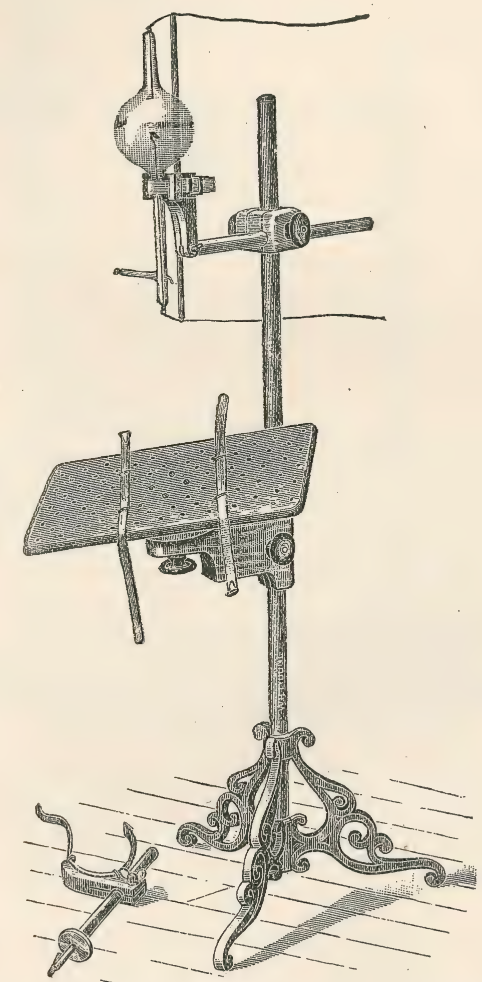


Fig. 1.—Adjustable standard with tube-holder and shelf for exposure of extremities.

Instead of illustrating all varieties of tube-holders here, the reader will find many of them included in other illustrations of the book. For instance, an upright "tube-closet" is pictured with the "Skiameter"; a Davidson cross-bar marked with centimetre scale and containing spirit-level is shown on his localizer apparatus; the tube-carrier for head-rest in radiography of the eye appears in another place; side arms on various tables are shown; several independent tube-holders enter into selected photographs illustrating technique in both the surgical and medical sections of this work, and by noting the special features of each, the reader will gain a general knowledge

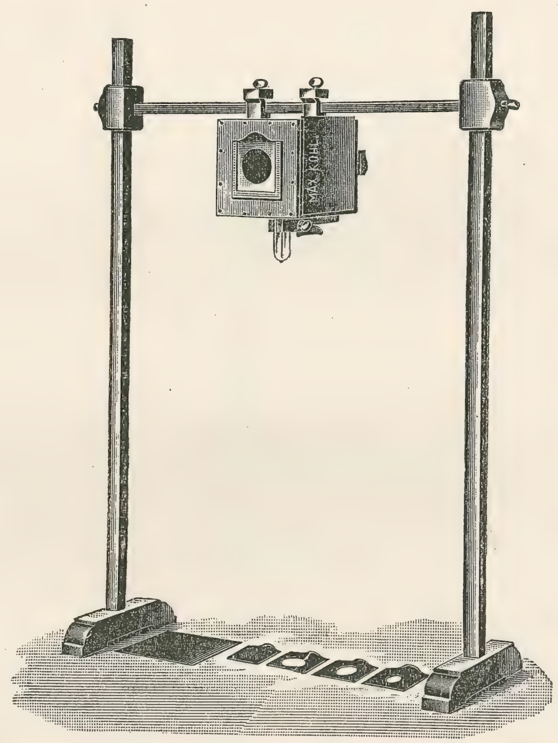


FIG. 2.—Dr. Levy-Dorn's "Protection Box" tube-holder with series of six lead diaphrams of assorted sizes. It is adjustable on the standard, and when the tube is used in the box it excludes all general light and allows only the X-rays that come through the window of the selected diaphragm to reach the patient. It is especially designed to avoid ill-effects from exposures to X-rays. It is lined with lead and is also fitted with an aluminum screen. In addition to the protection of patients it is also useful to regular workers in this field who are exposed several hours daily. Such a box will preserve their hands and eyes from injury.

of what actual experts use in actual practice. Avoid a shaky tube-holder, but a good device can be simple and moderate in cost.

Plate-Holders.—In the simplest form of X-ray work the plate is exposed in the envelopes now furnished by all dealers, but the use of photographic screens necessitates modification of the regular holder in common use by camera artists. Dealers supply them to order. They are so made as to take several sizes of plates. In ordering state the largest size. The plate must be changed in the dark room. No envelope is used when the plate is placed in this holder. It also acts as a support, preventing breakage. It can be used in

plain exposures if preferred to the paper envelopes, but is designed to permit the employment of one or two intensifying screens against which the film is placed and the holder closed. When closed it is light-proof till opened. All experts will find a good plate-holder invaluable.

Instead of using a metal backing for plates wrapped in paper envelopes or enclosed in the ordinary plate-holder, with its frame of wood, the combined objects may be obtained by making a *metallic plate-holder*. This will not only reinforce the exposure, but will exclude diffused secondary X-radiations. Simply make two rims of brass, one to fit snugly inside the other, and of a size to receive the photographic plate. Hinge them at the back and have them clamp shut in front. Over the front solder a very thin sheet of aluminum. Upon the back solder a thick sheet of brass. Line the largest rim on the inside with a strip of cloth so that when the now complete box is closed it will exclude all light. When the plate is inside this box

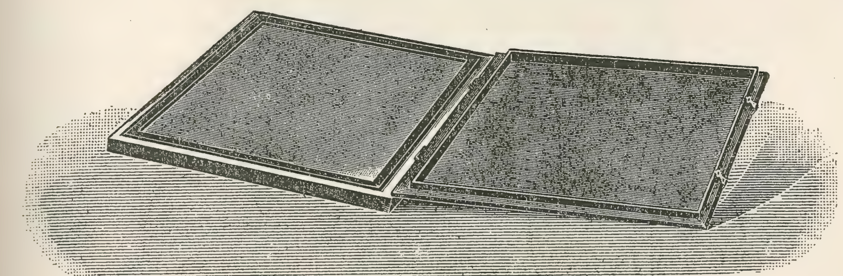


FIG. 3.—Shallow metallic box for holding plates as described in text with exclusion of diffused secondary X-rays.

it will be protected from breakage by pressure, from light, from diffused rays, and from the perspiration of the body. It will permit the use of a photographic screen. It will be thin, strong, and convenient, and, if made to take a large-sized plate, will also permit the use of all smaller sizes. The advantage of the metallic back of the plate-holder will be explained in another section.

Exposing Plate-Holder for Erect Positions of Patient.—To make the device employed by Von Ziemssen and Rieder in their *one-second* radiographs of the thorax (and which is useful from the feet to the head), proceed as follows: In a convenient part of the operating-room erect two narrow vertical runners sixteen inches apart, in the grooves of which will slide like a sledge the feet of a wooden frame with a front board 14 × 17 inches in size. On this front board tack a plate of smooth sheet-brass one-sixteenth of an inch thick to serve as a metallic backing for all plates exposed. On each side of the movable frame arrange a strap or means of steadying the part exposed in close contact with the film. On each side of the front of this frame arrange an adjustable piece to retain any size plate from 14 × 17 down to 8 × 10, with a narrow ledge below to complete the "holder." From the centre of the plate-carrier run a cord over a pulley in the top cross-bar of the apparatus with a counterpoise weight at the end so as to balance the exposing frame at any desired height to which it

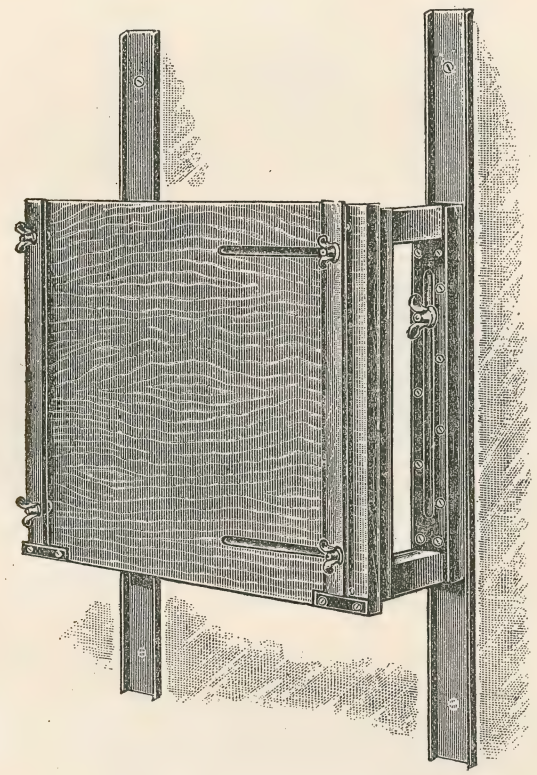


FIG. 4.—Sliding frame plate-holder for exposures of the thorax by Von Ziemssen's method described in text.

is moved. Add a set-screw to fix it in position when localized for the patient. From the most convenient side of the frame build out a permanent rigid arm for a tube-holder which will retain a fixed focus of the anode at right-angles with the exact centre of the frame and twenty inches from the plate, so that all plates exposed will be automatically centred without further detail. The frame and tube-holder being connected the tube will accompany all adjustments of the frame to suit the height of different patients, and of any part of the body

which it is desired to radiograph in the erect position. It will be found of great practical convenience, not less for the foot and leg than for the trunk. Sitting or standing patients can be posed in many convenient ways with this device.

Protection of Film from Heat and Perspiration of Patient.—When heavy parts are to be subjected to a long exposure during any season of the year when perspiration or the heat of the body would affect the film without protection, we may require something more than the ordinary envelope-wrapper. The use of a plate-holder obviates injury to the film by perspiration or heat, but when no plate-holder is used a piece of fine thin oiled silk, laid smoothly over the envelope, will keep out moisture. Both heat and moisture are preferably excluded by means of a very thin sheet of transparent celluloid, sold by art supply stores, and every operator should procure such a sheet. It should not be used when not needed to protect the film from heat or moisture, as every layer of material which separates the object from the film adds to the magnification of the shadow.

Examination Tables for X-ray Work.—The ideal table for this purpose is far removed from the surgeon's operating table in construction. It should be light, yet firm and strong; movable when desired, yet

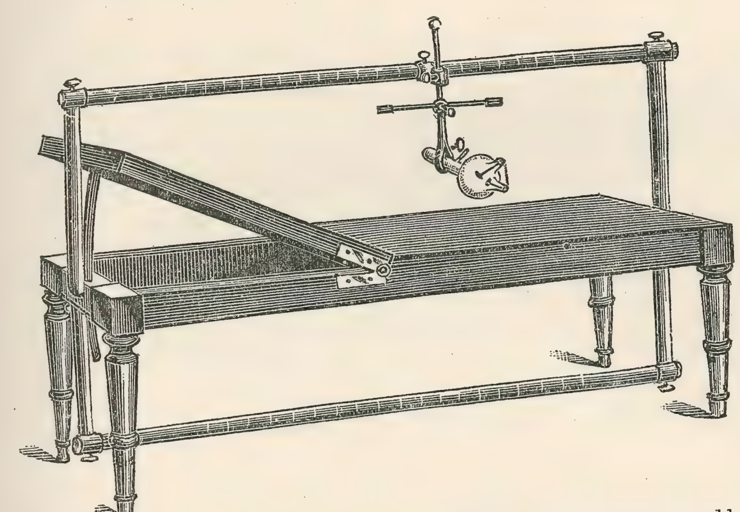


FIG. 5.—An X-ray examination table showing longitudinal tube-carriers above and below the patient. The jointed end can be raised or lowered to suit, the top is a thin, hard fibre which is transparent to the rays. Underneath and not seen in the cut is a traveling plate-holder for exposures with tube above patient.

steady during use; adjustable to all needed positions; should have a transparent top, removable in sections; should allow the ready placing and changing of plates; should carry its own tube-holder adaptable to all positions over and under the patient: should be compact and no larger than necessary; should have accessory blocks, frames, and clamps for immobilizing any part of a patient during exposure; and the top should be made to tilt or swing on a pivot by releasing mechanisms for this purpose. Couches, canvas-covered litters, plain tables, folding-chairs, and a number of special tables have been devised and employed for X-ray work, but there is still some room for improvement. If cost did not stand in the way, however, the ideal table could no doubt be made to order at the present time for anyone desiring it. A table of some kind is indispensable.

While operating tables and tube-holders are made in quite a variety, yet most of them contemplate all other positions of the tube save the important and often indispensable one of underneath the

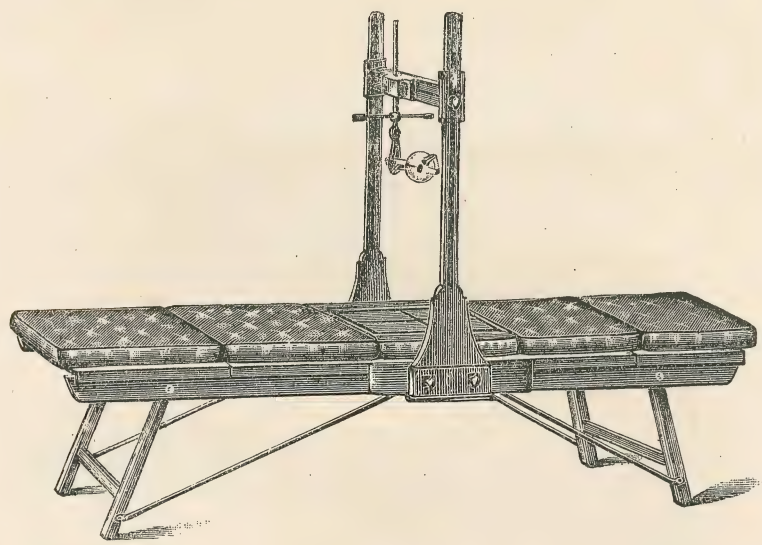


FIG. 6.—Example of X-ray examination table with sliding tube-carrier and cross-bar. The top is removable in sections, and the square seen under the tube and marked in quadrants can be shifted to center the plate in any other desired situation on the table. The millimetre scale on the cross-bar and the sliding adjustments of the tube-holder assist accurate work. It is one of the best and simplest tables made.

patient. Not only is it often important to place cases in the recumbent position and examine them with the fluoroscope, but it is absolutely essential to do so in the case of invalids whose disease or injury, or the state of anæsthesia, compels recumbency. An operator must be able to lean comfortably over the patient and use the fluoroscope in the axis of the rays. This requires a table lower than the usual surgical table, and it also requires what is lacking in almost all tables, viz.:

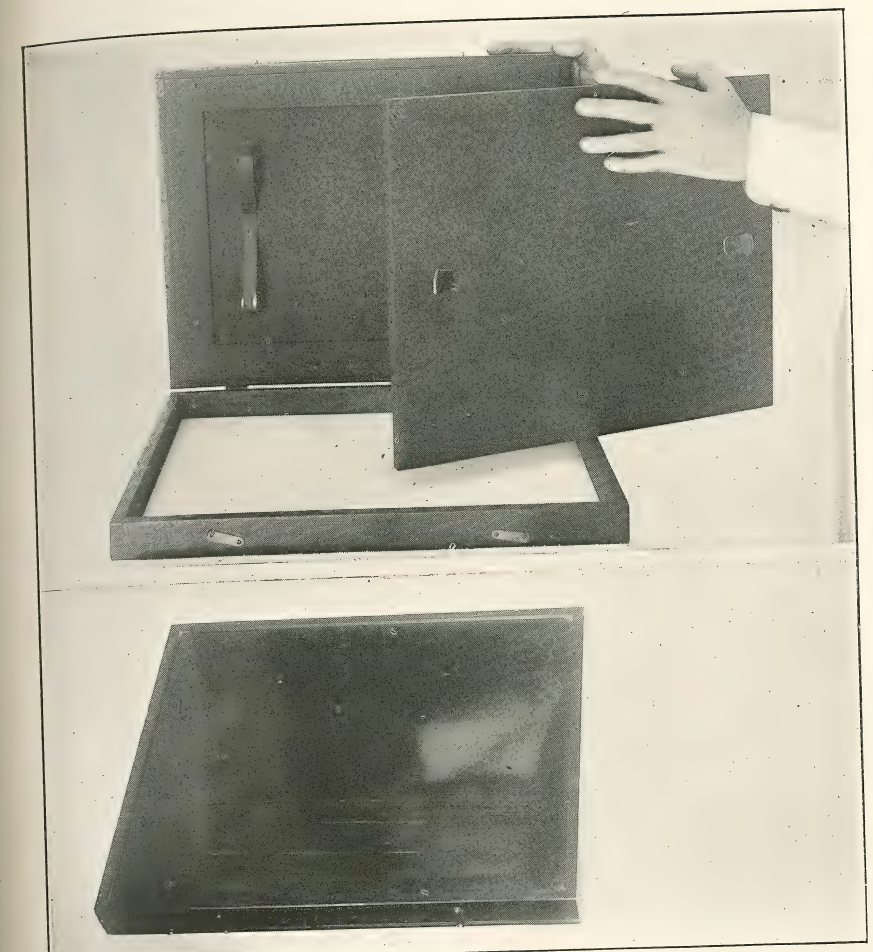


PLATE 9.—Author's Special Plate-holder. The upper figure shows the open box with white photographic screen laid in. Place the film down on this. Then lay over the plate the base which in the picture is seen steadied by the hand. Then close down the top and clamp it fast. The spring seen under the cover is one of a pair which press and hold the plate firmly against the thin ebonite sheet of the front. The lower figure shows the plate-holder closed and ebonite front uppermost. When placed in position on the operating-table lay the part on it and make the exposure as usual. Plates cannot break in this holder. It will receive any size from 4 x 5 up to 14 x 17.

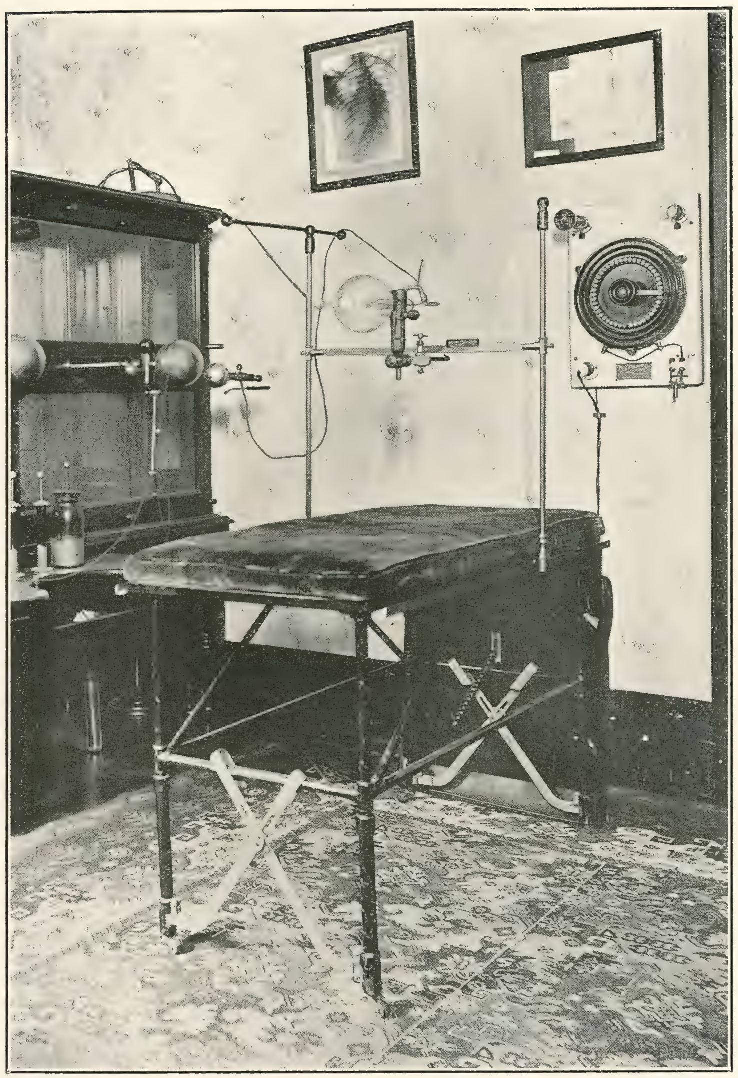


PLATE 10.—A Table with Cross-bar Tube-carrier and Scale. On the left pillar is a vulcanite spreader supporting the wires from machine. This plate and figures suffice to teach the general designs and accessories of useful examination tables, and these are modified in various ways to suit individual wants.

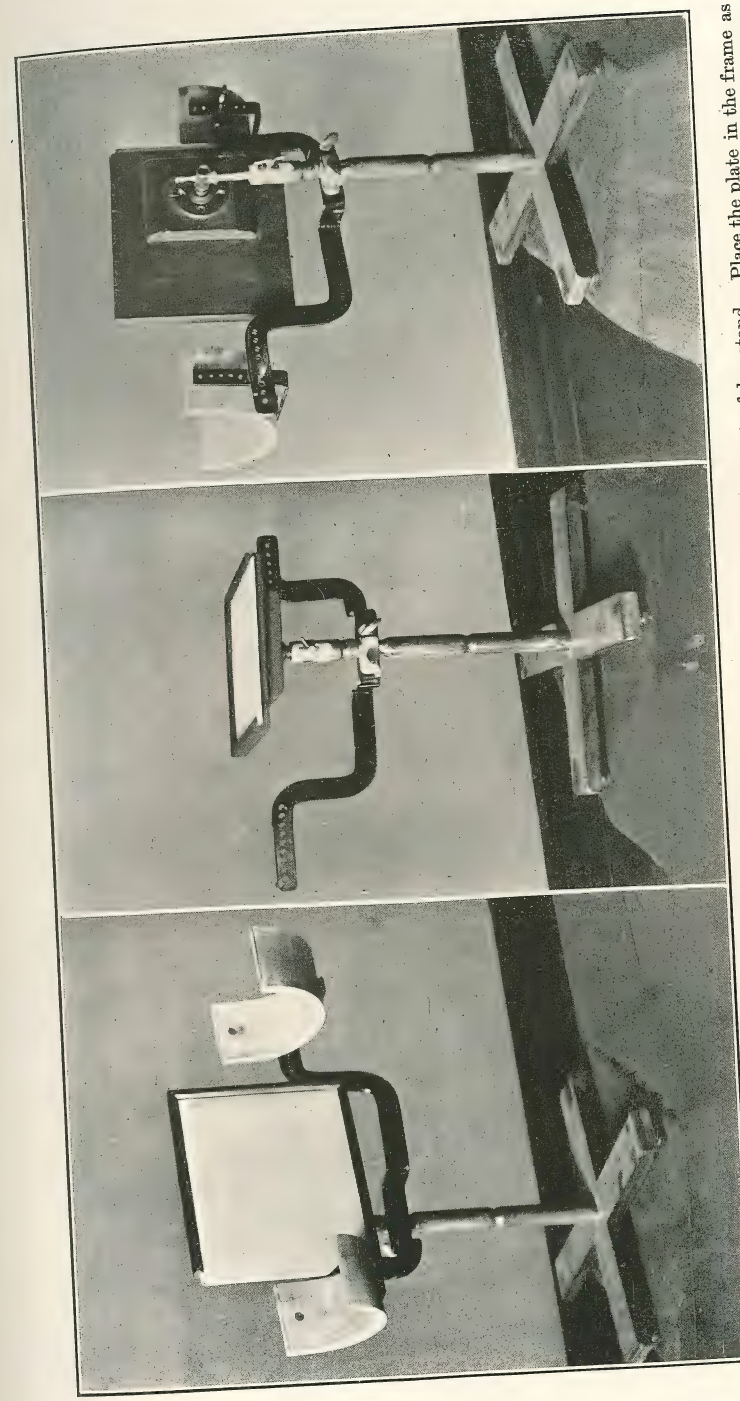


PLATE 11.—Stands for Leg and Arm Radiography. The right and left figures show back and front of leg-stand. Place the plate in the frame as shown; adjust the movable leg-holders to bring the part in relation to the plate and secure position with strap if needed. Particularly suited to lateral postures of a partly flexed knee. The central stand shows the same with leg attachments removed and in position for arm. The table top can be raised to any desired level. In subsequent plates the technic will be shown with patient.

PLATE 12.—Exposure of Arm with stand shown in previous plate. The tube and table supporting the arm can be raised and lowered as needed. Centre the anode, lay the photographic plate on the top, put the field of the part in position, and make the exposure. When once centred over the table the tube can remain ready for any number of subsequent exposures with axis effects.

a tube-holder which is fastened to the table, and is adjustable in any desired situation *below* the patient.

A canvas-covered stretcher built on a frame so that the top is pivoted and can be rotated from side to side and tilted up or down in the long axis is useful. The frame can be placed upon large, easy-rolling wheels, so that it can be moved readily, and should have a leg attached which can be let down to the floor when desired to steady it and prevent accidental movements when fixation is wished.

If a dependent tube-holder with sliding arms is constructed under the table, so that the tube can be shifted along its entire length with-

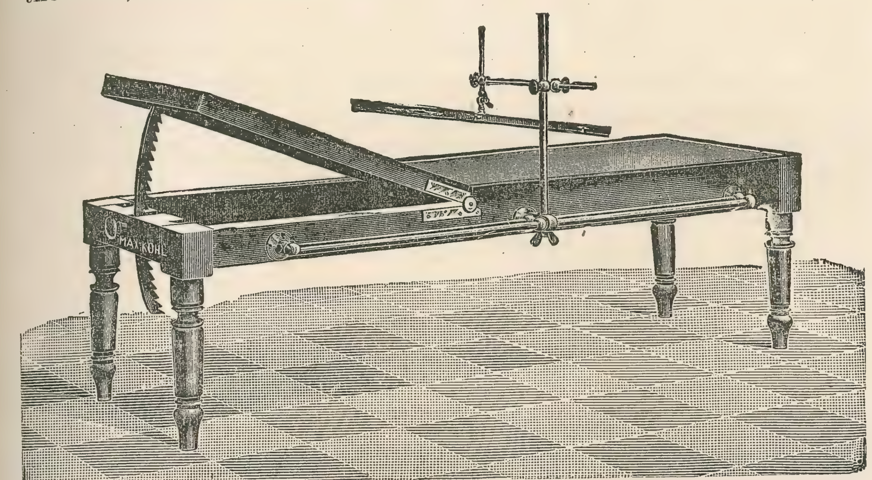


FIG 7.—X-ray examination table with holder for light-tight case containing the plate and intensifying screens. This holder is so constructed that the case with plate for radiograph can be placed in position either under or over the table.

out deranging the wires connecting it with the current, the stretcher will be complete. As men differ in height the individual having such a stretcher made for his own use should place a fluoroscope to his eyes and determine by actual test at what height from the floor he can comfortably bend over all parts of a recumbent patient, and secure a vertical position of the instrument with the screen horizontal to the path of the rays.

Exposing Board.—Not only is it more or less difficult to secure good pictures of the pelvis and hip-joint, but it is often difficult to pose the parts so that both sides of the median line, or both hips, or the necks of both femurs, or whatever two parts it is desired to compare, hold the same relation to the rays and to the axis of the body. To facilitate posing both lower extremities parallel to each other or in equal relations to the spine and plate, take a piece of plain pine board two feet wide and three feet long. At the lower end attach by a hinge-joint on each side of the centre a strip of the same board four feet long and eight inches wide at the top, and narrowing to five inches at the feet. Make the hinge-joint connecting the two leg-pieces with the body-board work laterally, so that when the leg-pieces are brought together in the median line the crack between them will continue a vertical line drawn on the centre of the body-board. Have each leg-piece separate equally from the median line by means of an adjusting cross-bar at the foot. Paint a plain black line down the perpendicular axis of the body-board and down the vertical axis of each leg-piece. Paint cross lines at right angles to correspond to the approximate levels of the shoulder-joint, the elbows, knees, and ankles, so as to indicate right-angled positions of the parts when the axis of the spine of the patient is on the median line of the board. Draw a definite cross line to indicate a line between the anterior superior spines of the ilium, and place the patient always in correspondence *with this mark and with the vertical axis.*

Next bore a series of three-eighth inch round holes, an inch apart, down both sides of the body-board equidistant from the middle axis, so as to bound the trunk of an ordinary person. Duplicate the series at lesser and greater distances from the axis so as to fit both thin and corpulent subjects. Run parallel series of similar holes in relation to the legs down the leg-pieces, and in relation to the arms across the body-board, so that the arms can be mutually posed at any angle from the body. Make a set of thirty round and straight wooden pegs to fit these holes firmly and stand up out of them five inches clear.

We now have a means of comparing the normal side with the injured or diseased side with absolute equality of relation to the X-rays.

To use the exposing board place it on top of the regular operating table and lay the patient on it so that the trunk fits snugly between two rows of pegs placed at intervals of a few inches down the line conforming to the previously measured width of the body of the given case. The axis of the spine will then fall on the axis of the board without other care. If the case is a hip-joint decide on the exact posture in which it is desired to show the injured or diseased side. If the neck of the femur is to be shown in its long axis fix the leg accordingly. By rows of pegs on both sides of the leg delimit its position and strap it fast to the leg-piece. It will now be immobilized at the desired angle for the exposure. On the duplicate leg-piece peg and strap the normal leg in the same manner. Separate the two legs equidistant from the median line so that the angle of the normal leg conforms to the adjustment of the other, and secure them in this situation by the cross piece at the foot of the appliance.

Or, if the arms or shoulders are to be compared, peg the two at equal angles from the trunk and strap them in equal positions on the same principle.

Other uses of the board will suggest themselves in a variety of cases. It gives bi-lateral comparisons with the utmost facility and can be easily made. For the exposure on one plate or two separate plates slip the plates under the parts, adjust the tube as indicated, and proceed in the usual manner.

A Body-Holder.—To aid in immobilizing the body of fidgety patients for a radiograph take two flat boards of well-seasoned wood, each twenty-two inches long, fourteen inches wide, and not less than half an inch thick. Join these at an exact right-angle and prevent warping by cross pieces at the ends. Make two belts of firm, thin webbing an inch wide and a yard long. Also two short belts a foot long for small parts. At one end of each sew a neat buckle. In both boards cut two sets of holes through which the belts will pass; one taking them horizontally and one vertically.

The side of this frame affords a support which the operating table lacks, and when placed on the usual table this vertical side can be made right or left as desired by simply turning the frame around. For a horizontal exposure of any part of the trunk of the body in either dorsal or chest position the addition of the frame to the table gives us a handy means of strapping the body so that the part exposed will not move. The frame can be clamped to the table easily, but it will usually be anchored by the weight of the patient. It can also be placed on a stand or laid on the floor or stood on an end. It is equally useful for exposures from above downward and from side to side. For centering the plate directly under the centre of the diagnostic field use the author's "Position Finder," as will be taught later, or employ the ordinary plumb line. Or, use the following:

Block and Pin for Focussing Anode.—An independent and ready position-finder and means of quickly focussing the tube in the exact axis of radiation with the plate at right-angles to avoid distortion is a block and pin. Take a smoothly planed pine block 3 × 3 inches thick and six inches long. Through the centre of the block drill a small hole at exact perpendicular so that it will hold a snug-fitting steel knitting-needle at right-angles to the base.

If a horizontal exposure is to be made place the tube in approximate position and start it into action. Then with one hand hold the block against the inner side of the frame so that the pin projects toward the anode from the point which will be the centre of the photographic plate when the exposure is made. With the fluoroscope on the outer side of the frame against the site of the block observe the shadow cast by the pin. Shift either the tube or the frame till the shadow *ceases to be a line* of any length and *becomes a mere round spot,* thus showing that the pin *coincides with the central axis of the rays.* Remove the block, place the plate and patient *over the spot thus marked* and make the exposure. The resulting picture will show a correct and non-distorted shadow of the parts under the axis of the rays. The simplicity of thus securing accuracy commends it, and a single test will demonstrate that a plumb line cannot be used to equal advantage. For vertical exposures sight the pin as described in section on author's regular Position Finder.

Effects of Secondary X-Rays during Exposures.—While the many published theories regarding the nature and action of X-rays would give no help to any surgeon in taking an X-ray picture, yet there are a few facts to be culled from scientific reports which have an every-day bearing on exposures for radiographs, and which all ought to know. Among these useful facts are the following:

1. X-rays are produced when the cathode stream strikes an obstacle. A dense metal is a greater obstacle than the glass wall of a tube, and, therefore, reflects more X-rays. Hence an artificial obstacle is placed in the tube to be struck by the cathode stream. As the electric-current generates heat the metal must not only be dense, but have a high melting capacity. Platinum is the most practical metal possessing these qualities, though osmium is better. The extreme rarity of osmium prevents its use except by a few. Makers have determined by many tests the best situation and angle in which to place the platinum anode, sometimes called "anti-cathode," or "reflector."

2. X-rays are also produced at the same time that the anode is active from its entire front surface and from a part of the walls of the tube, but the chief rays arise only from the small area on the anode directly struck by the long-axis point of the cathode stream. All others are lesser rays and impair rather than help our work.

3. X-rays themselves in turn send out new X-rays when they strike other bodies, even the air; so that if direct rays are cut off from a screen by a metal barrier in front of it some rays will appear to reach it from the sides, and it will still feebly fluoresce. This effect is not due to any bending of the rays, for they do not bend, but to the fact that while the original rays "radiate" from the anode in rectilinear lines straight from the focus like the spokes of half a wheel, the secondary crop of feebler X-rays emanating from collisions with air-particles are sent out in all directions instead of in radii only. These are the rays that need restraint lest they blur effects and dull the definition on the plate.

4. While the popular supposition is that in X-ray work we have to deal with shadows cast by a point of light, this is only in a measure true of the central rays of maximum efficiency, and the presence of lesser X-rays so enlarges the theoretical "point" of desired focus that if our eyes were directly sensitive to the rays a tube would appear, not as the ideal shadow-casting point, but rather *like a lamp in a smoke-filled room.* During long exposures of a plate these feebler rays have a chance to impress the effect of a penumbra around the borders of the net shadow from the real focus-point, while a short exposure more nearly escapes their action, and hence gives a sharper definition, as is well known.

5. Therefore the radiations from a tube are *mixed,* and the rays resulting from minor or secondary collisions are of different degrees of penetrating intensity, or so-called "absorbability."

The practical bearing of these few facts, for which our authority is Roentgen himself, will be appreciated by every surgeon who aims to advance his work and to properly interpret his results. The next section will speak of excluding secondary rays from the negative.

A Metal Background for Plates.—Among the various causes of blurred and indistinct negatives, especially when a low tube requires a long exposure, has been fluorescence of diffused rays around the plate reacting on the glass and creating a partial image from the sides. On the other hand, it has been shown that if the rays are checked at the back of the plate the fluorescence is intensified so that a more perfect image is secured in less time than from unchecked rays.

In 1898 it was quite common for expert operators to lay the plate upon a thick piece of plate-glass or to back it with a sheet of lead. Buquet, in 1897, reported experiments in radiographing a watch on a plate half of which was backed with lead and half not. The exposure was two minutes. The difference in sharpness of the halves of the picture was very marked. The part on the half backed by a cut-off of the rays gave sharp definition, while the other half was hazy and without detail. Many similar tests show that by arresting the actinic action of the rays we secure the effect of an increase of light, and the result is a better picture with a shorter exposure. Under ordinary circumstances, with improved apparatus, the average operator may feel that his results are good enough, and that a metal backing is not needed with a fine tube and a short exposure. Nevertheless, with any or the best tubes and with any length of exposure, the cut-out plate is a benefit to the negative. But even heavy glass is fragile and does not arrest the rays enough; lead bends and offers no advantage over brass. Therefore a base-plate of flat brass three-sixteenths of an inch thick is better than either glass or lead, for it is opaque enough and is a firm support on which a negative can rest without danger of breakage from the weight of the body. As the base of my "Position Finder" makes an ideal backing of this kind for arresting and intensifying the actinic action upon the film, thus serving two purposes at once, a description of it need not be repeated here. But any stout plate of metal will do. The routine use of such a backing is advisable and advantageous.

Combined Photographic Screen and Brass Plate.—An expert writes as follows: "The difference, if we use the tungstate of calcium screen over the dry plate resting on some *metallic* support instead of wood, is marvellous, and the results are really beautiful. In this way we both increase the sensitiveness of the film and accumulate more rays upon it, and reduce the time of the exposure. I have only one screen, 8 × 10 inches in size, and use the same in all cases of bone injuries, bone diseases, foreign bodies imbedded deep in soft tissues, fractures, dislocations, skiagraphy of the head, hip, knee, etc. The results obtained are most gratifying, and are very practical." The ordinary paper envelopes are not convenient for this work. But with a deep plate-holder, such as was made for me in August, 1896, taking readily my 14 × 17 photographic screen, any size plate up to 14 × 17, and the thick brass base of my position finder, at the same time, simply closing on them with a clamp, the process is as easy as the making of the usual radiograph. Any operator can succeed with it, as it presents no difficulties whatever. In other sections of this course more will be said on this subject.

The Diaphragm and Window.—Several experimenters, beginning with Leeds and Stokes in March, 1896, have employed a "diaphragm" for sharpening the shadows on X-ray plates. By the latter part of 1898 they had nearly gone out of use. Yet it is claimed that with the improvement in generators and tubes which has displaced the diaphragm it is really needed more than ever, "as a powerfully excited tube gives out X-rays over a greater area than the focus point on the anode." The device can easily be readopted.

One author has described with care and illustrated with cuts his own idea of a glass plate one-half inch thick, a foot square, and fitted into the front of a wooden box holding the tube. In the centre of this plate is a window three inches in diameter. Other plates have smaller windows for variations in the size needed in a given case.

He prefers glass to the metal plates used by other operators, and if the metal is not grounded his objection is valid.

But without additional detail or new device our X-ray gauge described in another chapter may be grounded and stood in place with the shutters up, and makes a practical and simple diaphragm for horizontal work.

As the object is to cut off all rays around the active field so as to lessen the *penumbra*, place the gauge between the tube and the fluoroscope or photographic plate, whichever is being used, and adjust it so that the axis of the rays passes through the centre of the window. Regulate its distance from the tube by the area of the field to be covered by the rays. If a larger or smaller window is desired by any operator a gauge to suit can easily be made.

Various experimenters often desire to employ exceptional devices to serve peculiar ends, and as even methodical operators here and there may find a home-made diaphragm useful, directions for constructing it will be found in the following letter from a prominent electrician:

"The employment of metallic diaphragms in radiographic work is objectionable on account of their conducting properties and their tendency to attract the high-tension discharge away from the tube. Very thick glass has been used, but such diaphragms are expensive to make and heavy and cumbersome to handle.

"Chinese, or the best grade of English, vermilion is nearly as opaque to X-rays as a silver coin when of the same thickness in a pure mass. For use mix it with a solution of shellac in grain alcohol, employing only sufficient shellac to make the vermilion hard and solid when dry, but not enough to impart any glaze to the dry surface. Make the mixture about the consistency of ordinary thick paint.

"Now take two pieces of firm cardboard of any desired size, say sixteen inches square, and cut in both a central circular window two and one-half inches in diameter. Give each cardboard a coat of the vermilion varnish on both sides, and when dry repeat. Dry and repeat again. Then freshly coat one side of each board and at once stick the two together, and under flat pressure dry them for several days. Then trim neatly, cover with plain protecting paper, and it is done. The combined thickness of the coats of vermilion is sufficiently opaque for ordinary radiographic work at exposure distances. I use a high-frequency coil which produces a strong spark-stream, and the discharge shows no tendency to leak across or through the diaphragm. It is cheap and easy to make, very light and handy to use, and nearly as strong as a metal screen." (ANDREWS.)

Lead-Covered Box with Diaphragm for Excluding Diffused X-Rays in Radiography.—Take the top and two ends of a plain pine-box.

Make top twenty inches square. Make the ends fifteen inches high. Over the outside of all tack a sheet of lead one-sixteenth of an inch thick. Reinforce the frame at the corners so it will be strong and secure. In the centre of the top cut a round window four inches in diameter. This completes the essential frame.

Next take four flat squares of heavy sheet lead, 5 × 5, and in each

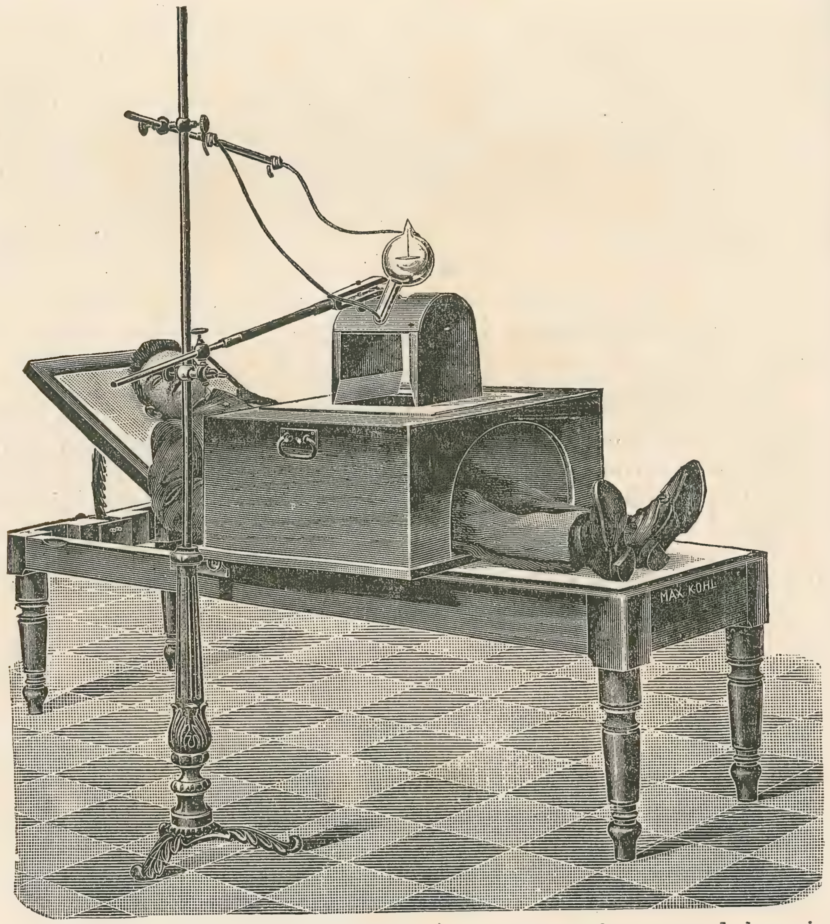


FIG. 8.—Lead-covered box with diaphragm for excluding secondary rays and sharpening exposures.

cut a round window. In use, a selected square (the diaphragm) is to be laid centrally over the window on the top of the frame so as to furnish the proper size of opening for direct rays to reach and cover the plate exposed. Hence the size of the diaphragm window will vary according to the area of the plate used and the height of the anode above the opening. Let the standard distance between the

PLATE 13.—Exposure of Knee with inner side on plate. Tube levelled at twenty inches with axis of rays striking centre of knee and plate. With different adjustments of the curved supports, any part of the leg may be postured at any angle or in extended or partly flexed fixture.

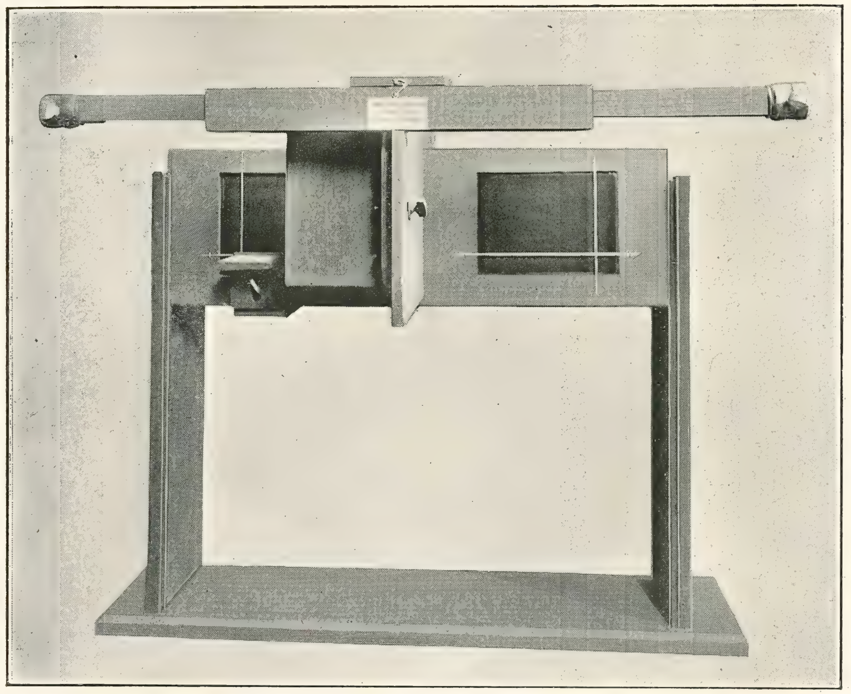


PLATE 14.—Head-rest for Ophthalmic Radiographs. Author's duplicate of Davidson's Head-rest for fixing the plate and head during exposures for localization of foreign body in the eye. To hold the head with absolute fixation while making two radiographs of the eye Davidson devised a head-frame which serves the purpose exactly. It is made stoutly of hard wood. The one in possession of the author is mahogany, and has a right and left side. The photograph shows it very imperfectly. A 5 x 7 plate fits in either side window. A chin-clamp fixes the head immovably in the desired position. This is one of the great advantages of the appliance. A sliding tube-carrier takes a tube in a fixed relation to the eye exposed. A scale on the arm measures the side displacement when stereoscopic radiographic pictures are made, and to facilitate stereoscopic exposures was one of the chief reasons for making the frame. The surgeon dealing with the localization of foreign bodies in the eye will find it indispensable. It may be useful for other head-fixations for radiographs.

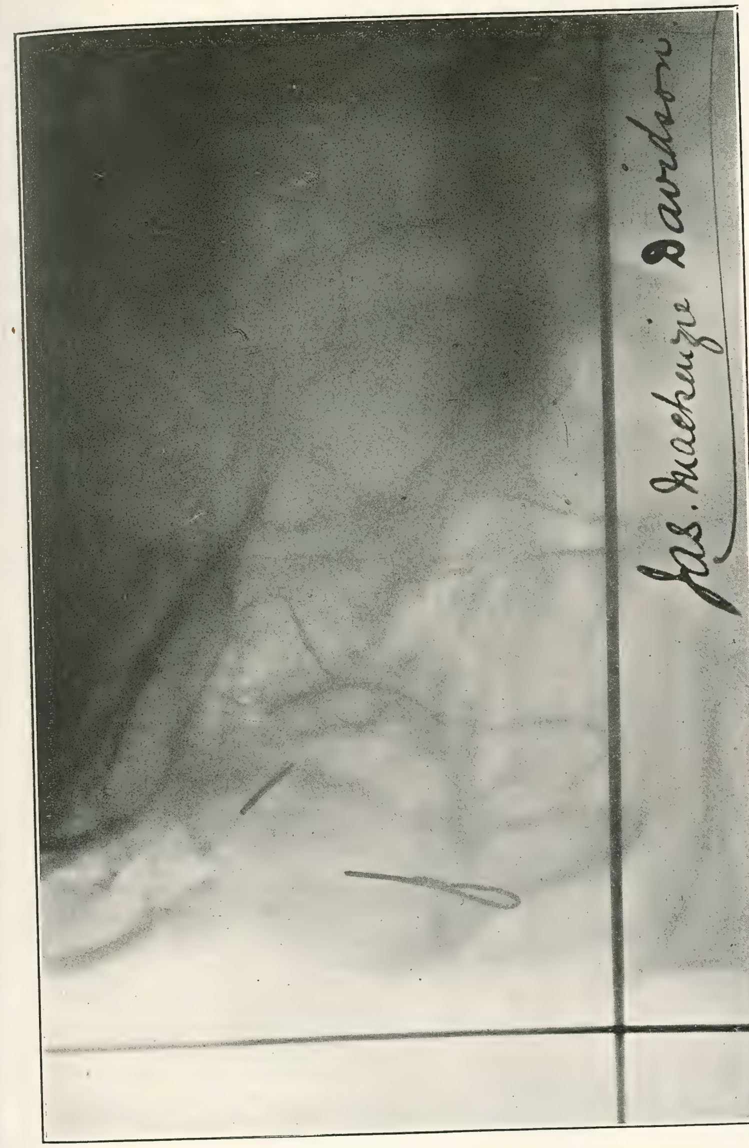


PLATE 15.—Example of Stereoscopic Radiograph of piece of steel in eye. The original pair were made by Mr. Davidson with the aid of his Head-rest illustrated in this volume, and the steel was exactly localized by him with his Cross-thread apparatus also illustrated in this volume. The loop is the lead land-mark fixed on the eyelid. The lines of the rods are the means of registering the prints in exact apposition in the stereoscope and are seen in the cut of the Head-rest. The half-tone has lost much of the fine detail, but is instructive.

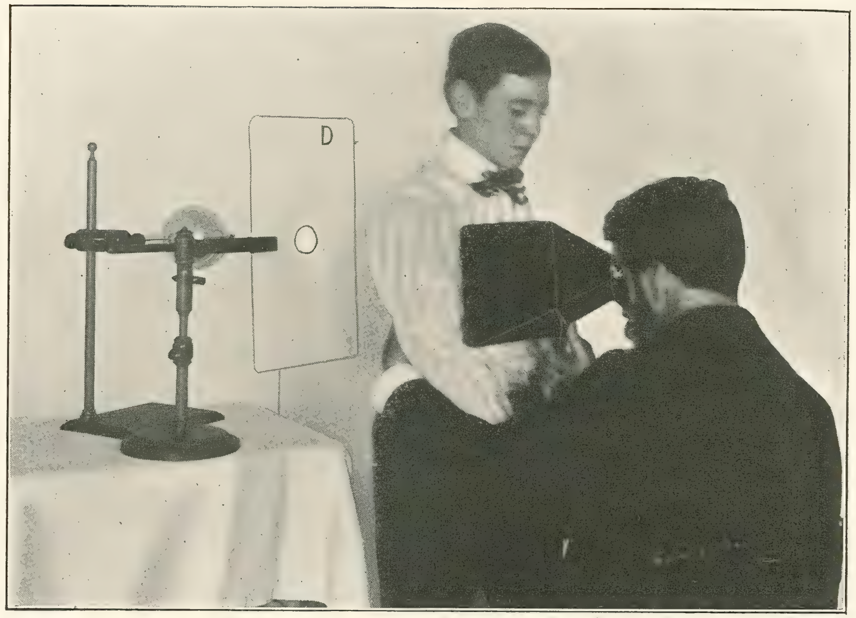


PLATE 16.—Fluoroscopic Inspection with Diaphragm between patient and tube. The Diaphragm partly hides the light of the tube from the eyes, and also cuts off most of the X-rays except those coming through the small window in line with the focus. Note that the examiner's left hand presses the patient up to close contact with the screen, a fundamental need in fluoroscopy. Any tube-holders and support for the diaphragm may be used, and those here shown were selected merely for convenience in making the photograph. The tube and path of rays through the window being fixed, keep the screen in the illuminated field, and shift the parts of the patient successively into the field of the screen. This insures a correct and undistorted view. The picture fairly illustrates a suitable method of inspection of the chest with all factors in relation.

anode and the plate be twenty inches. The frame being fifteen inches high, the opening in the diaphragm upon its top may be five inches from the anode, or can be exactly measured with a rule. Refer to the author's Divergence Chart and note the diameters required to cover the field of such sizes of plates as the operator most uses, and cut them accordingly.

In use, select the square with the window adapted to the size of the given plate, place it in position, and, after adjusting the tube and patient, block up the frame so that the diaphragm will be as close to the wall of the tube as possible without attracting the current. Then make the exposure as usual. The box can be grounded if desired. It is simple, inexpensive, easily handled, and effectively shuts out the secondary rays which tend to blur the lines of a radiograph, particularly with long exposures. The accompanying illustration is taken from a more elaborate box employed in Germany. With distance and window adapted to the area of the lesion the same device may be used instead of a so-called "lead mask" in the exposures of X-ray therapy. By standing it on its side on the edge of a table it can also be used for exposures in the sitting posture.

CHAPTER IX

SCREENS

Photographic Intensifying Screens. Protecting Metallic Screens.

The word " screen " has been commonly applied to the chemically-coated front of the fluoroscope, or the open fluorescing sheet which the X-rays make luminous to the eye; to the similar but differently finished sheet of coated paper made to fluoresce against the photographic film and intensify the actinic action of the rays and shorten exposure-time; and also to various sheets of metal, aluminum, lead, etc., which have been employed to " screen " the patient's tissues from by-effects in therapeutic exposures. The word *screen* does not well fit these different uses, but none other has been coined. We will now take up the different forms of screens in regular order and study them. The fluoroscope will be considered in another chapter.

Photographic Screens.—On or about April 3, 1896, the author saw for the first time a negative, part of which had been reinforced with a tungstate of calcium screen. It plainly showed the more rapid activity of the rays on the covered portion of the plate, and with the feeble apparatus then at the command of the operator he believed that he had found a most valuable means of shortening the time required for a successful radiograph. Later experience showed that tungstate of calcium was better than the barium salt for this purpose, even after tungstate had been abandoned for the fluoroscope, and that it needed to be prepared with exceedingly fine grain to minimize the marbling of the negative. The preparation of these screens reached a high state of perfection here during 1897, and makers advertised them as a routine item of equipment. Since 1900 they have been still further improved and popularized in Europe.

They do not deteriorate with age, and only require to be kept flat and free from handling to last indefinitely. The 14 × 17 screen purchased by me in August, 1896, has always been preserved in a plate-holder, and is still as good as new. Nothing but the film of the plate, or its wrapper of fine tissue-paper, has ever been allowed in contact with the chemical side of the screen. This care preserves the original delicacy of the fine coating.

That such a reinforcement of fluorescing activity will affect the sensitive plate in less time than rays without the screen is apparent on the first test; and the rapidity is doubly enhanced by using two screens, one under the plate as well as over it. On the subject of these screens an English author thus writes:

" It has been proved by prominent workers that the use of a fluorescent screen in conjunction with a photographic plate very materially reduces the exposure required for any special case with a given outfit. It is, of course, the actinic fluorescence of the screen, which, acting directly on the plate, helps to build up the photographic image. But as the ordinary photographic dry plates are not uniformly sensitive to every kind of ray we must either have a screen which fluoresces with a photo-chemically active color, or, if we wish to use a barium screen which fluoresces a yellow-green, we must first orthochromatize the sensitive plate. As the latter process is somewhat troublesome and plates thus prepared do not keep long it is best to use a screen which fluoresces with a purple light, and for this purpose tungstate of calcium in a certain modification offers great advantages.

" The best intensifying tungstate screens are coated on a flexible support, and so evenly that very little, if any, grain or marbling will be noticed on the negative. The matt side of the screen is the coated one, and must be placed in direct contact with the film of the plate. For this purpose, therefore, a special plate-holder is required, as the envelope wrapper now furnished with X-ray plates is not convenient for the reception of the screen.

" If we coat *both sides* of the photographic plate with emulsion, and produce images in both coatings which are identical in density and in perfect register, we can obtain negatives which, for equal exposure, yield greater density; or, for equal density require only one-third the exposure of the one-sided plates and films. This system of double-sided coating is of special value in conjunction with intensifying screens, since it enables us to use two screens, thus greatly enhancing their action. The plate in this case is sandwiched between the two screens, and *the respective exposure is about one-ninth that required with an ordinary plate without any screen.* Such an arrangement will be found especially useful for the radiography of thick parts of the body, the thorax, pelvic, and abdominal regions."

As all the early observers reported that the gain in quickness of exposure was at a loss of clear detail, experiments were made to ascertain the cause. A systematic study of effects, with strips of five different screens on sections of the same plate, showed in the negative that the action of screens of different material and quality was quite different. Those which fluoresced with a violet tint gave the best result, while the platinum salts impaired the impression. The sharpest *definition* was obtained when there was no screen used. With the screen there was produced a sort of halo around the edges of the image, but this was not due to the granular nature of the material, but to a true halo caused by the diffusion of the light. This effect, being due to the fluorescent radiations, therefore increases with the time of exposure, but is obviated by using a metal backing as we show elsewhere.

With the gradual improvement in generating apparatus, tubes, and X-ray technics, the shortening of the normal exposure-time through greater efficiency of radiance lessened the opinion of the profession that an intensifying adjunct was a necessity. A screen, also, adds to the thickness of the cover of the plate-holder, lifts the part still farther from absolute contact with the film, and, at short-distance exposures, contributes to magnify the image. Recently addressing the makers of the leading fluoroscopes in this country with an inquiry as to the present sale of photographic screens, we had the following reply:

"Photographing screens are now seldom used in America, so far as we are able to judge. Some operators use them regularly, but they are ordered so infrequently that we no longer keep them in stock. Our opinion is that X-ray apparatus, and particularly photographic plates, used for this purpose, have been so improved that the use of a screen in connection with the plates is now generally inadvisable."

But let us consider the matter a little further. The finest intensifying screen of tungstate of calcium does not blur the picture very much. If it was helpful with inferior apparatus may it not be still helpful with improved apparatus? A case in point is recently cited relating to the detection of a gall-stone. Five exposures were negative in result, but on a sixth attempt the persistent operator placed an intensifying screen over the plate, made a brief exposure of fifty seconds at thirty inches, and secured "two gall-stones in the gall-bladder, one giving a very dark shadow on account of the phosphates, and the other, having a nucleus of cholesterine with phosphates around, not so plain." An operation was done, and the two stones found corresponded very exactly to the shadows in the skiagraph.

In this case exact *definition* was not the main need of diagnosis, but rather a *contrast of densities.* And this *points to the proper function of the photographic screen, and a revival of a greater usefulness than before.* To summarize:

1. When the diagnosis demands the clearest definition and sharp details of anatomy with distinctions that the screen would blur, do not use it.

2. When thin and easily skiagraphed parts are exposed no screen is needed.

3. When thick parts are exposed and the diagnosis does not involve the most absolute definition of structure but is rather a matter of contrasts and relation, the screen will greatly lessen the time required, and thus not only taxes the patient less, but also reduces the possibility of accident.

4. When a foreign body is sought the screen will catch the shadow on the plate with a reduced exposure-time, and with all its aforesaid advantages.

5. When slight contrasts of density are involved, especially in fields of soft tissues, the screen will fix the low-density shadow most quickly, and reduce the liability of losing it by a slower penetration of the denser parts. Calculi illustrate this. Under-exposures are apt to be avoided by the aid of the rapid-action screen.

The fact that experts secure calculi and other difficult shadows on plates without the aid of any screen does not indicate that any operator may not be greatly aided at times by employing it. Objectors can certainly find fault with it, but the general operator who tries to get all the help out of it that he can without any other idea than to do good work will find a photographic screen of considerable value each year that he uses it.

The above relates to *ordinary* radiography. When we come to consider the high clinical value of the *momentary* radiographs of the great German experts in thoracic diagnosis and observe that without the "intensifying screen" they cannot be generally secured, we see that they take us into a field of work which *the photographic screen has made its own,* and which does not admit of argument. Ask Levy-Dorn, Von Ziemssen, Rieder, and their many followers whether such an accessory is needed to-day or not, and they will point to a brilliant array of cases—cases in which they feel the greatest pride, and describe with satisfaction—and show that in this special field the screen is *indispensable.*

One of the foremost radiographers in England recently summarized the European status of photographic screens, in 1901, as follows:

"With respect to plates our friends across the Channel are not better off than we. They, too, are limited to plates which, however excellent for ordinary work, are deplorably deficient for X-ray records. To compensate for the insufficiency of absorption of the X-rays in the film, intensifying screens are largely made use of on the Continent, as in England, particularly since the grain has been reduced to a minimum and in the vast majority of cases does not interfere with the usefulness of the picture.

"Frequently two screens are used, one on either side of the plate (or better, film), no matter whether the latter has only one or both sides coated with emulsion. Especially when using films a second screen is a decided advantage. The specimens here shown (of instantaneous radiographs) were made on Schleussner films coated on one side only, but sandwiched in between two intensifying screens of calcium tungstate. They were made at twenty inches with a twenty-inch coil, an electrolytic break, run by the 100-volt continuous electric-lighting circuit. Exposure was made with an instantaneous electric-light switch in the primary circuit of the coil. The extreme rapidity of the exposure is clearly shown by the sharpness of the outlines of the respiratory organs, and as a further gain of the short exposure we notice a well-marked contrast in the shadow of the different tissues."

We have observed that some operators speak with impatience of the mere idea of using these screens, but dogmatism in the matter, or a "dog-in-the-manger" spirit, is out of place, for each operator seriously searching for the truth about the advantages offered by any X-ray device can *test* the matter and take no untried verdict. Some "do not *like* screens"; others say they "*try* to do without them"; but those who have made the best and most frequent use of fine screens state that they shorten the exposure about one-seventh. Some have made one, two, or a "few" trials of screens, and, regarding them as unsatisfactory, have abandoned them. But it may be recalled that in X-ray work there are a number of different view-points. When diagnosis is the end aimed at a picture may suit a surgeon when the enthusiast aiming at spectacular effects might reject it with disdain. An all-round radiographer certainly can find some valuable uses for a fine pair of screens, and when he does not need them they can be set aside. In preparing this course of instruction we sought an impartial opinion in the following manner: We requested an expert to make a set of tests, placing a part on one large plate, and dividing the plate into sections. One section to be a plain exposure; a second section to employ a screen, but to have no metallic backing to the plate; the last section to use both screen and metal backing. No test was made with two screens as the operator had but one. We have before us the prints from the resulting negatives and the report of the physician. He asserts that the tests made according to my directions prove the advantage of the screen, especially when the plate *is backed by metal*. As reproductions lose so much of the original, it will be impossible to place the evidence before the reader in a satisfactory manner. The half-tone print is not a fair substitute for the negative, and readers cannot judge of one from the other.

Metallic Protecting Screens.—What is meant by a device thus named is a sheet of opaque metal over the tissues exposed for diagnostic or medical purposes, or a transparent sheet of thin aluminum connected with a wire to earth.

In surgical exposures for diagnosis the protecting screen originated from a desire to keep from the exposed tissues the particular rays that caused X-ray burns during the making of radiographs. These screens are generally a very thin sheet of aluminum, and are not cut with a window. They are not put on the skin or over any pasteboard mask, but are supported by the tube-holder much nearer to the tube itself than to the patient. One is usually connected to a gas or water pipe to "ground" it, and to carry away electrostatic discharges. Many metals and other substances have been tentatively employed for this purpose during the past five years of radiographic work, and opinions as to their need and value differ.

Where one operator uses such a device a hundred do not. It is wise to expose the patient by modern methods that call for no "protection" rather than to create a risk by poor practice. So far as known to the author none of the world's leading masters of radiography use a grounded screen in taking their pictures. With 1902 apparatus it seems superfluous.

In medical work the purpose is to shield the healthy tissues around the lesion from possible ill-effects, while the action is limited to the diseased part. To let the rays pass to the diseased part a hole is cut in the metal sheet corresponding to the area of the lesion, or surface treated. In medical work on the face a common pasteboard mask is often used as the backing and layers of tin-foil are laid on its front, save over the area to be treated. Or, a piece of sheet-lead is cut and bent to fit over the face. For any part of the body the principle is the same, and the arrangement of the device is governed by convenience.

The metals most used are sheet-lead and tin-foil, as they are easily cut, are cheap, and can be obtained in various thicknesses. Do not lay the metal directly on the skin of the part, but either support it at an appreciable distance or put a layer of cardboard, blotting-paper, or cloth under it on the skin.

No such devices as "lead masks" are for sale by dealers so far as the author is aware, and the ingenuity of individual operators prepares what is needed for a given patient. They are improvised affairs, some holding that *they are not required at all. Some use them because it has been the mode, and for fear that failure to do so will lay them open to charges of neglect of proper technics.* Time and experience will settle the matter.

In a discussion on the subject of protecting screens, Payne remarked:

"I made several experiments with screens, which I mentioned in a discussion a year ago. It seems to me that if you have a metal screen, and it is touching the body, you will have a different effect from that which will result if the screen is a little way off. If the metal screen is touching the skin, the latter will not be protected from the discharge. If, on the other hand, it is a short distance away, and grounded, every impulse given to the tube by the coil will induce a charge on the screen, which again may have an effect on the skin by induction. The metal screen does not seem satisfactory. If the screen could be made of some highly insulated material, we should perhaps get rid of these defects. If we could devise a screen that would keep off any electrical effects or discharges other than the X-rays, we would be able to determine whether the X-rays have any therapeutic effects, or not."

We have in plain, dry, tightly woven *paper* such a highly insulating material as Payne desires. A fine quality of paper, in a perfectly dry state, is a better insulator than glass, and is equal, if not superior, to the best hard rubber. For years I have employed it as a protector of the tissues in certain applications with high potential electricity, and it is very transparent to X-rays. It does not need grounding, as it is not a conductor. It does not set up induction. It is cheap, always at hand, can be cut and shaped to suit, and does not spark at the edges when in the electro-static field. By using a greater or less number of sheets, or employing sheets of cardboard, the desired thickness can be regulated to suit the needs of any case.

Flexible Lead Mask.—Take a clean piece of soft linen of sufficient size to more than cover the part; take a piece of sheet-lead about as thick as an ordinary business card and a little smaller than the linen; make a paper pattern of the diseased area and then cut out the lead a trifle smaller, so that when laid on the part the hole will fit just within the margin of disease; sew the linen and sheet of lead together, and fold the edges of the linen over all borders of the lead so that no metal contact will be made with the tissues, especially around the hole applied to the lesion; then adapt the completed mask to the part and attach tie-strings to hold it in place during treatment. This has some advantages over a mask made on a cardboard foundation.

Do not forget that as healing takes place and the affected area shrinks, the hole in the lead shield must be reduced to fit as accurately as at first. Do not make the mistake of treating a lesion that has become one-half its first size with a shield cut to fit the original area

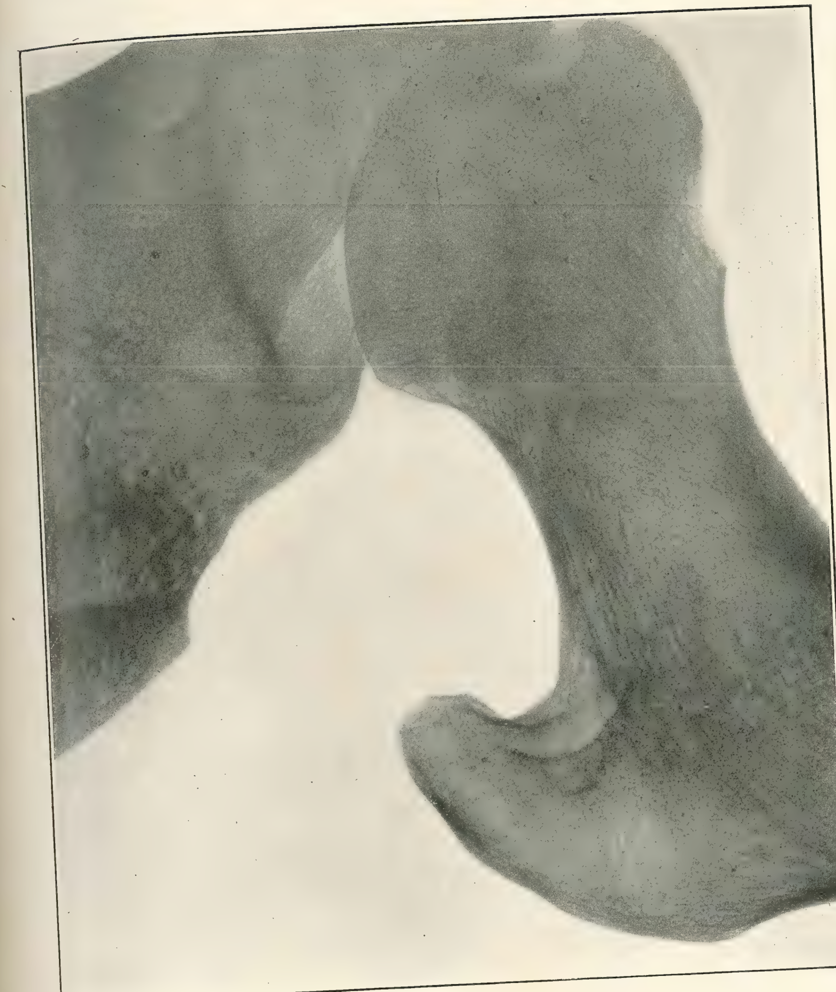


Plate 17.—Section of Hip-joint showing definition obtainable with intensifying screen. Radiographed by Dr. Jicinsky. Exposure ten minutes with tube at twenty inches. Dislocation of femur discovered by the X-rays. Had been diagnosed as fracture of neck without the rays. Allowing for loss of detail in reproducing processes it will be seen that a fine tungstate of calcium screen laid on the film to assist the exposure does not necessarily mottle and blur the picture. The original print of this radiograph in the author's hands is beautifully clear and would please any critic.

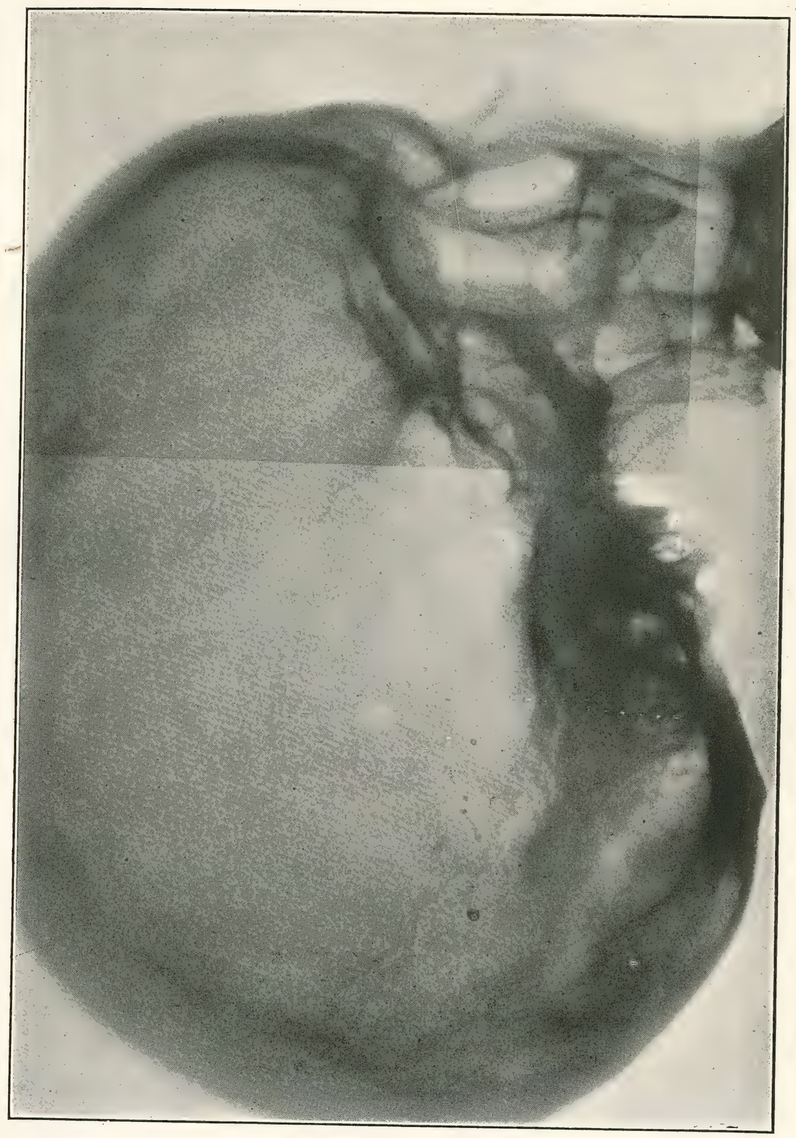


PLATE 18.—Another example showing definition obtainable with photographic screen on film. Radiographed by Dr. Jicinsky as a test for this book. Several others are omitted for lack of space, but this head and the section of hip suffice to show that the screen does not spoil the detail as some claim. Compare these radiographs with our text on this subject.

PLATE 19.—Rheumatic Gout of the Hand. "Closely inspected this picture presents some interesting features to the expert and contains evidence questioning the diagnosis of rheumatic gout. If it illustrates bone changes that have not been supposed to be caused by this disease, but which may occur in its late stages, the X-ray will alter the common opinion of the ultimate nature of the alterations set up in the tissues." (Rebman, Ltd.)

PLATE 20.—Calculus in the Left Kidney. In this case all the ordinary signs of renal calculus were absent, but a stone was suspected and was held to be in the cortex of the kidney. The radiograph changed the diagnosis into a certainty and the operation secured from the centre of the kidney an oxalate of lime calculus three-quarters by one-half an inch in size. Tube, 18 inches; time, 8 minutes; 10-inch coil. The reduced picture here shown fails to do justice to the negative.

This picture is a print from an electrotype from a fine half-tone reproduction from a print from a fine negative. In the four steps from the original to this page the entire value of the picture has been lost, and it is here inserted only to point out to those who form a poor opinion of an X-ray image from such illustrations as this that their judgment is based on wrong premises. Blurred reproductions are not the basis of the diagnostic value of the X-rays.

and never altered. Keep a supply of heavy foil or thin sheet-lead on hand, and fit new shields as needed.

Lead Shield for Malignant Disease.—In the X-ray treatment of the superficial forms of cancer which are being treated in increasing variety and success by X-rays, the rule for fitting the hole of the shield over the lesion is exactly opposite to that for lupus and ulcers. The fact that deeper portions of the growth extend under the margins of the apparently healthy area of the skin makes it of the first importance to include a sufficient margin of tissue in the exposure to the rays. Recurrence or subsequent extension in early cases reported may be traced in part to the omission of this detail of technic. All directions in this course relating to making the hole smaller than the actual area of disease apply to other conditions than cancer, or to lesions which are largest at the surface. Any lesion which may be larger below the surface than the area of the skin-line should have treatment directed to its maximum extension even if covered by normal skin in part. Remember this general principle of application.

Various writers have remarked that the metal of a mask should not touch the skin as "it would cause irritation," but none explain *why*. The truth is that if the metal really made *contact* with the tissues there would be no irritation. There may be a great difference between "touching" a part and *electrical contact* with the same part, just as there is a vast difference between a cook's idea of a clean knife and surgical cleanliness of a knife for an operation. Electrical contact is not a mere approximation, but *a continuity of conduction between two conductors.* When a current of high voltage is discharged in a room it charges metallic objects within its electro-static field. These in turn discharge to the great magnet, the earth, or to any other object brought near enough to attract the charge. If there is any insulating space between the charged body and the attracting object the discharge will fly across it in the form of a small spark or series of minute sparks, and these are like the sharp needle-sparks familiar to all who use static electricity.

With the small currents used in X-ray work, and with the metal of the mask apparently touching the skin of the patient, it does not make electrical *contact* if there are dry hairs or scaly dry skin between the current and conducting tissues. If they were wet with water hair and crusts would conduct the current without the minute spark-gap, but when dry they act as a resistance and force the current to jump across them to reach the tissues. Then the energy expended sets up heat and irritation; but if the metal is removed just beyond the minute distance which the discharge can jump across, it is insulated from the tissues and hence does not attack them with the small sparks. Therefore, to eliminate these we may either insert too much resistance by lining the lead with cardboard, etc., or we may cut out all resistance by actual electrical contact, or we may carry off the discharge silently by a metal conductor to earth. In the latter case the patient will not feel it at all, for all currents take the path of least resistance.

Read this explanation carefully and appreciate the simple statement of facts that puzzle many whose experience has been without instruction. To "ground" the mask hook a light chain or wire to a convenient gas fixture and hook the other end into a hole in one corner of the mask. When this is done there is no further question of "keeping the metal from touching the patient's tissues."

Selected Tin-Foil for X-Ray Masks.—Practitioners and hospitals seldom know where to get the most suitable foil for X-ray work, and it will render a service to many to give the information here. Speaking for this city we find sheet-lead in plumbers' supply stores, but the thinnest kept in stock weighs about three pounds to the square foot. This is too heavy for face-masks and for close fitting to a part. Price, eight cents a pound at retail. After much search and many inquiries we have traced head-quarters in the manufacture of all kinds of tin-foil. For facial shields and all cases requiring a medium, flexible, and easily moulded foil the kind to get is known as "Tea lead foil No. 1." It is neat, clean, silvery, and can be ordered in any size, sheet or roll. One pound yields a sheet a foot wide and four feet long. The retail price is ten cents a pound. For additional thickness use more than one layer when needed. It is made by "The Conley Foil Company," Nos. 521 to 541 West Twenty-fifth Street, New York, who will furnish it to physicians and hospitals in any quantity. Their name is mentioned here simply as a kindness to my colleagues, to whom the knowledge of where to procure the foil is worth far more than the slight cost of it. Heavier foils are also made by this firm, but are less readily shaped about irregular parts. It is well, however, to have some of the heavy foil on hand for flat uses.

CHAPTER X

STUDIES IN THE OPERATION OF X-RAY TUBES

A Study of Electrical Dosage. The Essential Bombardment. Tests. Static Methods. Fluctuations of Tubes. The Travelling Focus. Dosage of Current for Tube a Factor in Avoiding Dermatitis. Magnetic Augmentation of X-Radiance.

What may be called the dose regulation of current for Crookes tubes possessing a suitable vacuum involves practically three features of control—pressure, volume, and interruption. On the *pressure* and *quality of interruption* depend the intensity of the bombardment of the cathode stream upon the anode, and on the *volume* of the electrical discharge depends the opulence of the rays—the factor which gives richness of detail to the picture. Therefore, the regulation of dosage to adapt the electric-current to the production of the required degree of X-radiance is as essential as the proper dosage of drugs for desired therapeutic actions.

In the regulation of coil-currents the form of controller which governs the primary voltage and amperage is an obvious mechanical device, which requires no skill to operate. Practically, nearly all requirements of judgment and experience relate to the *interrupter*. As every coil-current is an interrupted current the only question is the regulation of the particular device upon your own apparatus. About 100 varieties of interrupters have been distributed by different makers among X-ray workers prior to this date. For the most part they are variations of spring vibrators, revolving wheels, electrolytic, and mercury, types; but the exact regulation of each is peculiar to itself. The many pages required to instruct the reader without knowing what type he possessed would be wasted, and it is a simple matter to have the seller explain the switches, set-screws, and combinations of the coil you purchase, at the time it is delivered. Certain principles, however, can be set forth here.

High intensity in the bombardment is required to transform the current at the cathode and atomize it. Simple continuous *pressure* will not best accomplish this object, however high the pressure may be. It requires a fusillade of *blows*. This is beautifully illustrated with the Static machine.

Connect the suitable tube directly to the prime conductors with the poles drawn widely apart, and without any break in the electrical conductors. Start the machine slowly into action and watch the cathode. The tube will light up with a dull glow, no activity will be visible on the glass nearest the rim of the cathode, and the fluoroscope will show that very feeble X-rays are developed. Next increase the speed of the plates a little. There may be a slight increase in luminosity, but inspection of the cathode shows that there is no *furious bombardment* from the electric-current such as is needed for the development of efficient X-rays.

As the current from the Static machine is next increased, the pressure will reach a point when it breaks down the resistance between the rim of the cathode and the neighboring glass wall of the tube. Now, observe the effect. Like the halo round a picture of the sun we see fine streams of sparks infinitely small radiating upon the glass. The bombardment has changed from simple pressure into the rapid-fire volleys of intense strain, *which must be set up by some means somewhere in the circuit* in order to excite X-rays. The dull glow of the tube instantly changes to the apple-green radiance which delights the operator. The fluoroscope shows rays of richness and penetration. The necessary *interruption* has been supplied by the *discharge between the rim of the cathode and the glass*, without the aid of any external break.

Tubes which are well adapted to work with Static machines will supply this form of interruption steadily, without noise, without strain upon the tube, with scarcely more than blood heat, and with a brilliancy of radiance equal to any that can be obtained with equal currents. Owing to variations in the pressure, a tube, however, is liable to intermit this cathode-rim discharge, and with its disappearance the X-rays diminish. But in every case, when it takes place steadily, it illustrates with great beauty and clearness the principle of X-ray excitations, and affords a means of study from which the operator can learn much. To become independent of chance in establishing the essential intensity of bombardment, an *external interrupter* is employed which can always break the current and maintain steadiness of action. When the external interrupter acts as the intensifier watch the cathode, and note that the radiations to the glass are altered. The substitute break of the current dominates them.

With all varieties of therapeutic Static machines, there are three methods of operating a Crookes tube.

1. Direct Current.—Connect the tube to the prime conductors by the usual wires. Draw the poles a foot apart. Start the machine into rapid action. If the tube immediately lights up, simply regulate the speed of the plates to produce the desired degree of radiance. If the tube does not promptly fluoresce with a pressure current push one sliding pole toward the other until a spark jumps and disturbs the circuit. A tube will often light up after one or two sparks. If it does so draw the poles again apart, and the tube is ready for work. This method of using the current requires a tube which furnishes its own bombardment from the rim of the cathode. It requires neither Leyden jars nor interrupting devices, but there must be a *bombardment* somewhere.

In my original work, written when my largest Static machine was but half the size of what may be considered the present standard, it was recommended to connect the largest Leyden jars beneath the pole-pieces without making the circuit between their outer coatings. It was considered that they might produce a possible reinforcement of the current, although carefully tested effects with and without them failed to distinguish any difference. With the development of currents of higher efficiency from much larger machines than the ordinary eight and ten plate thirty-inch machines in general use, I have long since ceased to pay any attention to Leyden jars in connection with X-ray work.

2. Interrupted Direct Current.—This is the most practical and certain method to employ. Place a pair of the author's interrupters upon the handles of the sliding poles of the Static machine, so that the terminal ball of each interrupter makes contact with the outer ball of each prime conductor about one inch from the joint of the vulcanite handle. Shift the collar of the interrupter back to within half an inch of its own vulcanite handle and screw it securely upon the handle of the prime conductor. Do the same at the opposite pole. Connect the wires from the tube either through the eye of the flat piece below the collar of the interrupter, or to the brass rod behind it.

Start the machine into action with the balls of both interrupters in contact with the balls of the two prime conductors, so that there is no interruption in the circuit. Draw the poles widely apart. As the tube either dimly or brightly lights up slowly twist the handle of the negative interrupter so that the metal ball upon the curved end of the metallic rod of the device will gradually separate from the ball of the Static machine and open the spark-gap. The length of this spark-gap may be varied from infinitesimal thickness to about an inch by a simple twist of the handle. It may be done very slowly or with a quick movement, according to the action desired.

To regulate the proper length of spark-gap, vary it while watching the tube, and when the tube works at its best or supplies the desired degree of X-radiance, the dosage is adjusted so far as the negative interrupter is concerned. If, however, a greater length of spark is needed, pull the rod directly through its retaining sleeve till the ball of the interrupter is drawn as far away from the ball of the prime conductor as may be desired. The maximum distance is limited to that through which a steady spark-stream will pass, or approximately, two inches.

If the bombardment is not yet sufficiently *intensified*, repeat the same process at the positive pole, and increase the speed of the plates. The development of the maximum current of the machine, and the maximum spark-gaps which can be regulated to steady action, represent the limit of the apparatus with a given tube. The principle of operating other forms of Static-machine interrupters is the same. Makers vary the shape of the device but not the principles of dosage.

These interrupters not only steady a flickering tube, but enormously increase the efficiency of tubes of medium and low vacuum-resistance. They practically add their own spark-gap to the spark-gap rating of the given tube, with the advantage that the *external* resistance is always adjustable. They greatly aid to drive the current through any tube whose resistance is somewhat high, but not too high, for the capacity of the given Static machine.

It is generally an improvement to interrupt the current at *both* poles with a *low* tube. It is generally advisable to interrupt only the *negative* side of the current with a high tube. All points of regulation are, however, independent of theory, for a moment's test demonstrates to the operator exactly what to do.

Besides the particular form devised by the author the same principle is applied to other designs of Static machines by what are called " spark-gap posts." It is simply a matter of mechanical form. The manner in which the spark is made to break the current is not important if the quality of action is secured.

These interrupters are adjusters of the total resistance of the circuit auxiliary to the vacuum-resistance of the tube. In addition to this, they are regulators of the intensity of the electrical bombardment of the cathode, and thus fulfil three important functions. Until they were introduced the dosage of the direct Static machine current was dominated by the internal state of the tube. By their aid the situation is reversed, and the wide range of flexibility they impart to regulation of the current enables the operator to dominate any and all tubes below an excessively high exhaustion. They steady

the action of the formerly uncertain current-pressure as a firm grip steadies a wavering arm.

They, of course, produce satisfaction in proportion to the *fatness* of the current with which they are employed, and *currents from more energetic machines than the ordinary eight- and ten-plate sizes demonstrate their value most effectively.* It may be said here in passing that too much of the general measure of the efficiency of static electricity is ignorantly based on observations of small currents, which deal with both tubes and tissues as a hatchet (instead of an axe), would deal with a large tree. No woodman witnessing the chopping qualities of a large and keen axe would hold up a hatchet as the standard of working efficiency, yet the common idea of static electricity is founded on currents of but hatchet size.

Author's Short-Circuit Stick.—When a coil is used for X-ray work a switch cuts in the full current at once and in the same manner cuts it off. But when the Static machine is used the current increases gradually and does not attain its maximum till rapid speed of the plates develops, and when the revolving plates are slacking up the current dies out by degrees instead of by a sudden cut-off. For this reason exposures for radiographs cannot be limited to an exact number of seconds of maximum radiance when starting and stopping the Static machine in the usual way. A means of creating an immediate short-circuit is necessary.

In my early teaching of X-ray technics I was accustomed to use the brass rod called the " shepherd's crook," but, being metal, its use may be annoying to those who dislike the contractions at the wrist which occur at the moments of make and break, especially when a powerful interruption energizes the current. A non-conducting *handle* corrects this fault. Such a device is indispensable and is made as follows:

Take any thin strip or stick of light wood four and one-half feet long. On one flat side of this narrow stick tack any convenient strip of metal, or small chain, or wire, that will serve the purpose of a conductor from the distal end of the wood along twenty-eight inches toward the handle. This leaves a long end of the wood free from metal, and this is used as the handle end.

In practice, when all is ready for the exposure except exciting the tube, take this short-circuit stick by the bare wood end and lay it across the poles of the Static machine so that the wire or strip of metal on the distal half will bridge over the space from contact on one pole to contact on the other. Start the machine into action (with the adjustment known from previous test to be required to properly work the given tube), and when full speed is attained lift away the stick. While the stick is on the poles no current reaches the tube at all. When the stick is lifted the full X-radiance begins sharply, and the time can be noted to a second with the watch.

When the time is nearly up take the stick and stand, watch in hand, beside the machine. At the precise second desired lay the stick across the poles, and the metallic circuit instantly shunts off the current from the tube and the X-rays cease action. There is no sensation to the operator or patient, and the simplicity of the method is perfection. The same device enables us to cut off the current at any moment to adjust a contact, tube, wire, or any part of the apparatus, or to substitute another tube, without delaying to stop and re-start the Static machine. The cost of the instrument need not be three cents, but its practical utility is worth many dollars in time, convenience, and satisfaction. No Static-machine operator should remain a day without one. It is also useful in therapeutic practice.

3. Leyden Jar Current.—Connect the terminals of the tube to the outer coatings of a pair of smallest Leyden jars connected properly with the prime conductors of the Static machine. Short circuit the sliding poles and start the current into action. Gradually draw the poles apart three, four, five, six, eight, or more inches (according to the machine), until the maximum or desired degree of radiance is secured with the image still steady. Do not separate the poles so widely that the spark-stream becomes irregular and causes flickering of the image on the screen.

Remember that Leyden jars reverse the direct polarity of the prime conductors. If you have forgotten this and do not succeed in obtaining satisfactory X-rays on the first attempt, with a medium or low-resistance tube, turn it around and try it the other way. With the Leyden jar method, some X-rays will be produced, even when a tube is connected with the cathode to the positive jar.

High-vacuum tubes are not suited to the Leyden jar shunt-current as it cannot handle the resistance. Use only the very small Leyden jars, for the reason that the discharge must be rapid, and it takes large jars too long to fill and empty. If in doubt about the matter simply make the experiment, and the objections to jars of two or four quarts capacity will demonstrates themselves.

Dosage of Current for a Given Tube.—While the amount of current required to excite a tube is proportioned to the size and internal resistance which it presents to the current, yet the two factors, voltage and amperage, here go hand in hand together as they do in so much of the work of electricity. A small tube of a given resistance

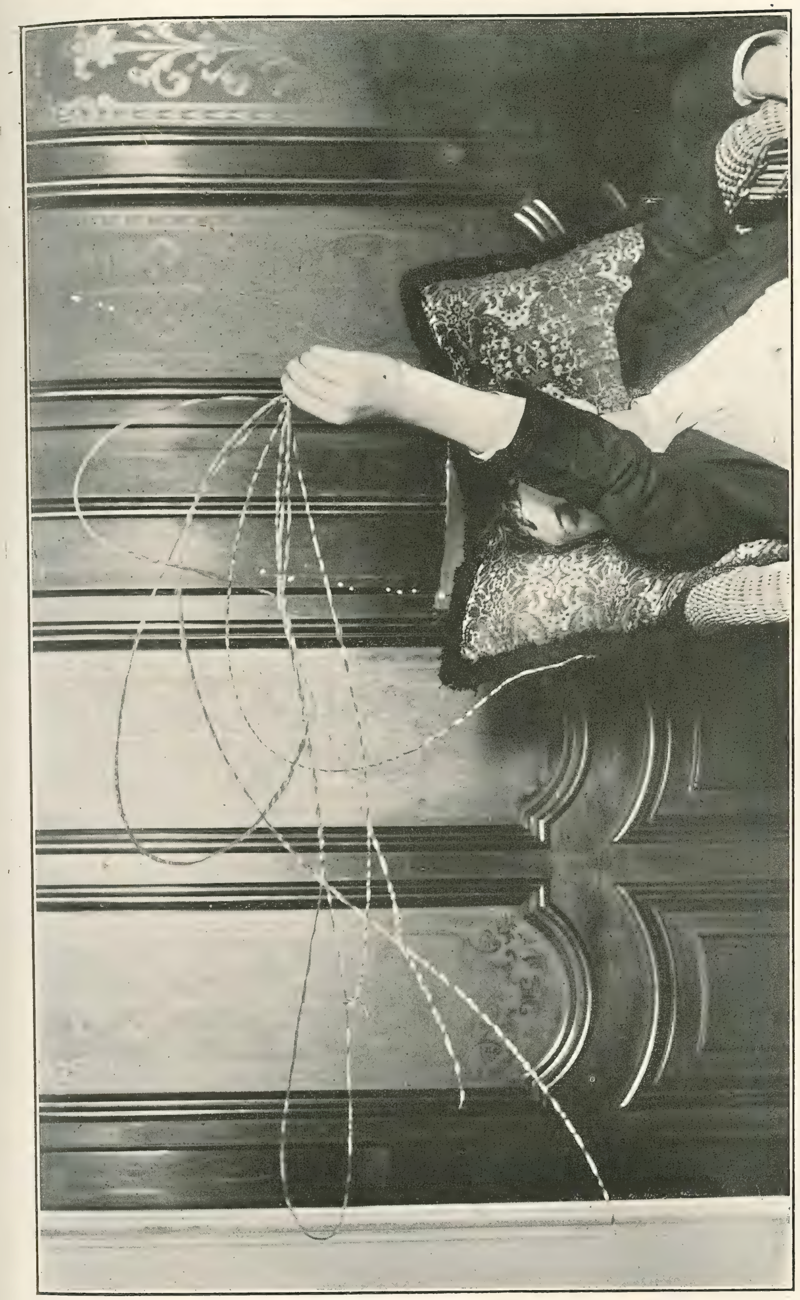
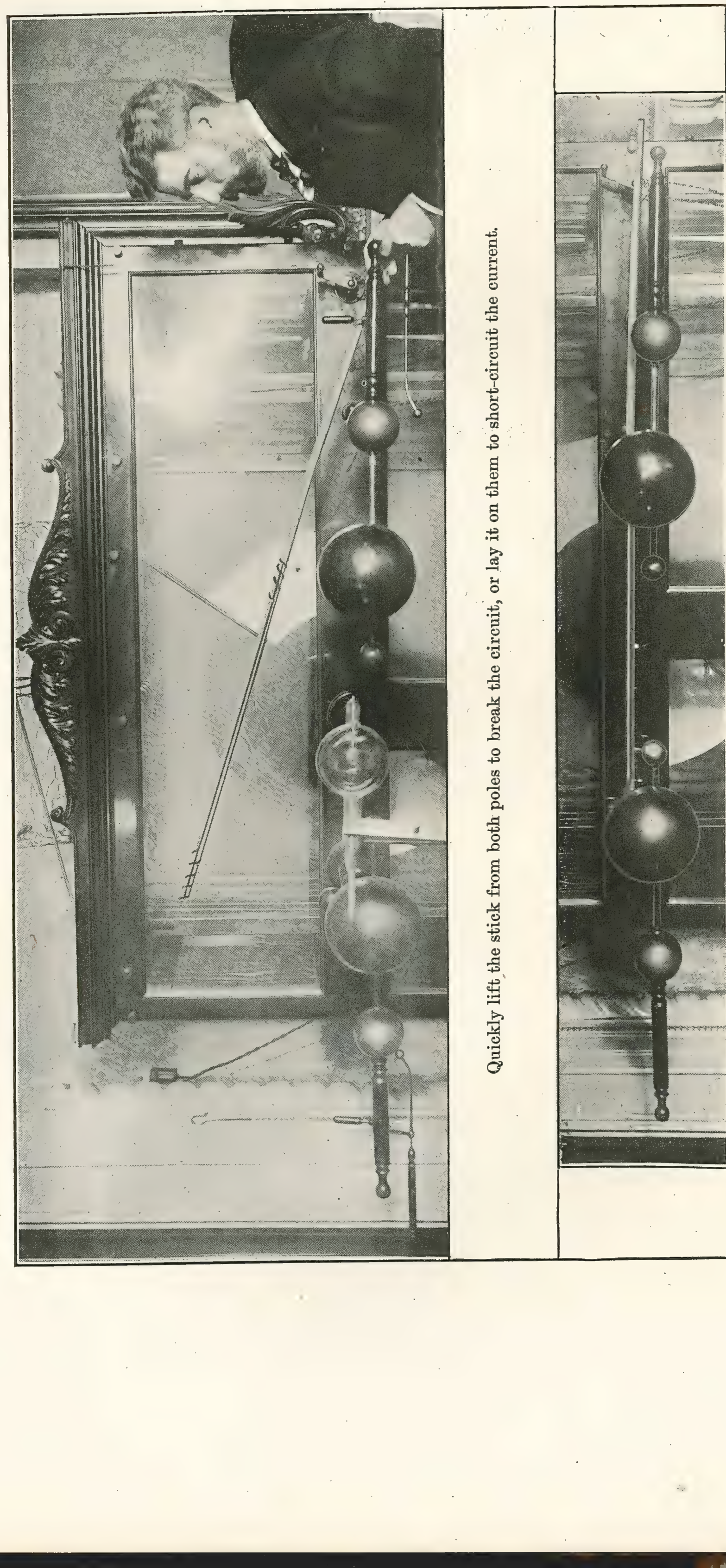


PLATE 21.—Author's Test for Tension of Static Current. Sit on insulated platform and ground either pole. Let out strands till they fall to floor. Note degree of strain. Then let them fly from the hand. A large current will hold out six feet of light cotton cord and drive it ten feet or more when released. This far surpasses the usual spark test. A current not equal to this illustration is too small for fine X-ray or therapeutic work. The author's machine is at the right of the patient and omitted from the cut.

(This photograph was taken in the author's office during the "dog days" of 1901, when the humidity was reaching 88, 91, to 95 degrees, according to official reports. The strands extended by the current in the picture are only 44 inches long, but the tension would throw them ten feet when released. From the first week of July till the author left the city September 9th on his vacation this machine never discharged, even while idle over Sundays each week. This fact is merely stated to show the working of the Static machine in summer in the author's hands.)



Quickly lift the stick from both poles to break the circuit, or lay it on them to short-circuit the current.

PLATE 22.—Author's Short-Circuit Stick. In the lower figure the stick is laid on the poles and shunts the current from the tube. In the upper figure the operator is seen lifting it from the poles to let the current excite the tube for the required exposure-time. See text for full description.

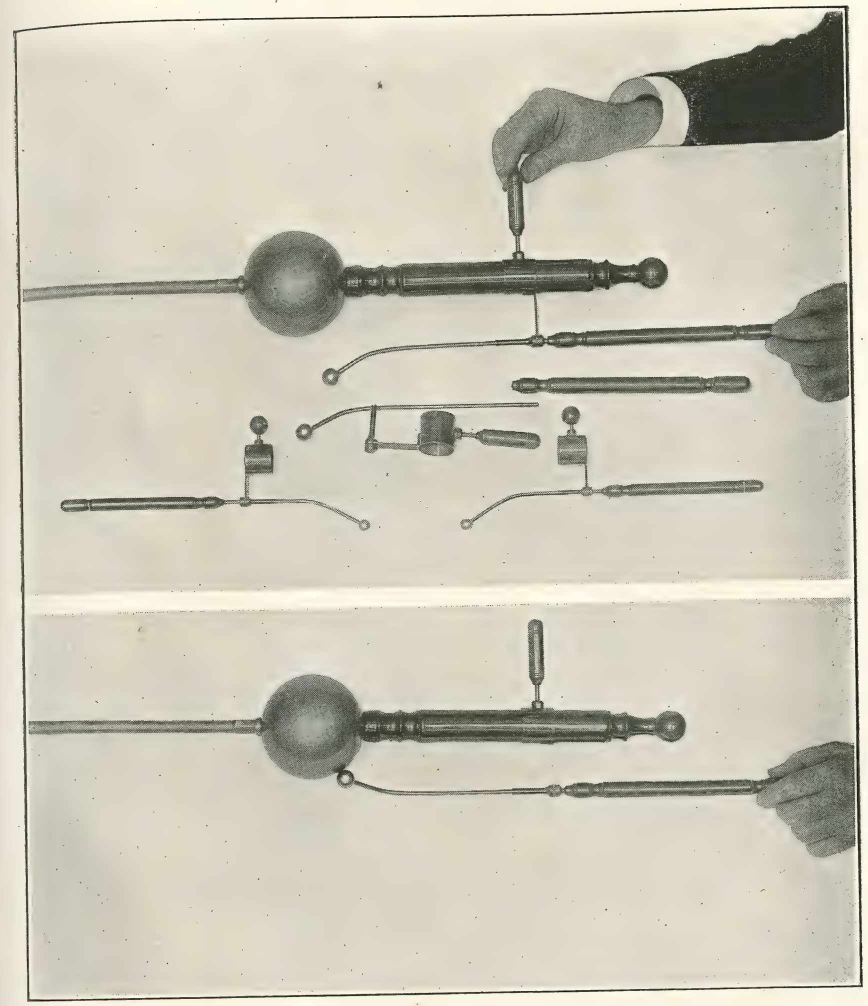


PLATE 23.—Author's Interrupters for large Static Machines. Slip the metal collar of one Interrupter over the vulcanite handle of the Static sliding pole and fix it in place with set-screw as shown in upper illustration. The spark-gap between the balls is here open. To close the gap and use a continuous current make a half turn of the handle till the balls meet as shown in the lower figure. To increase the spark-gap more than a turn pull the handle of the interrupter through its sleeve and away from the prime conductor. To clean and polish the brass parts take the interrupters apart as shown in the upper figure. The smaller pair shows right and left positions of the interrupters when on the opposite poles.

The model pictured in my original volume early in 1897 is here greatly improved upon. The newer insulating handles are nine inches long and protect the operator from sparks when regulating the powerful current. The long handle to the set-screw is a convenience. It is of prime importance to have the rod fit tightly in the sleeve through which it turns and slides, so that when the ball is placed in contact with the direct conductor of the sliding pole, or at any desired distance from it, it will remain fixed. It is equally important to keep the brass parts of the interrupters polished. Oxidation upon the rod and terminal ball reduces conductivity and impairs the fine quality of the break. The same is true of the brass parts of the poles of the Static machine. Observe particularly the bend in the rod of the above model. The advantage of this curve is easily seen in practice, and the author has not used a straight rod in any of his interrupters since 1898.

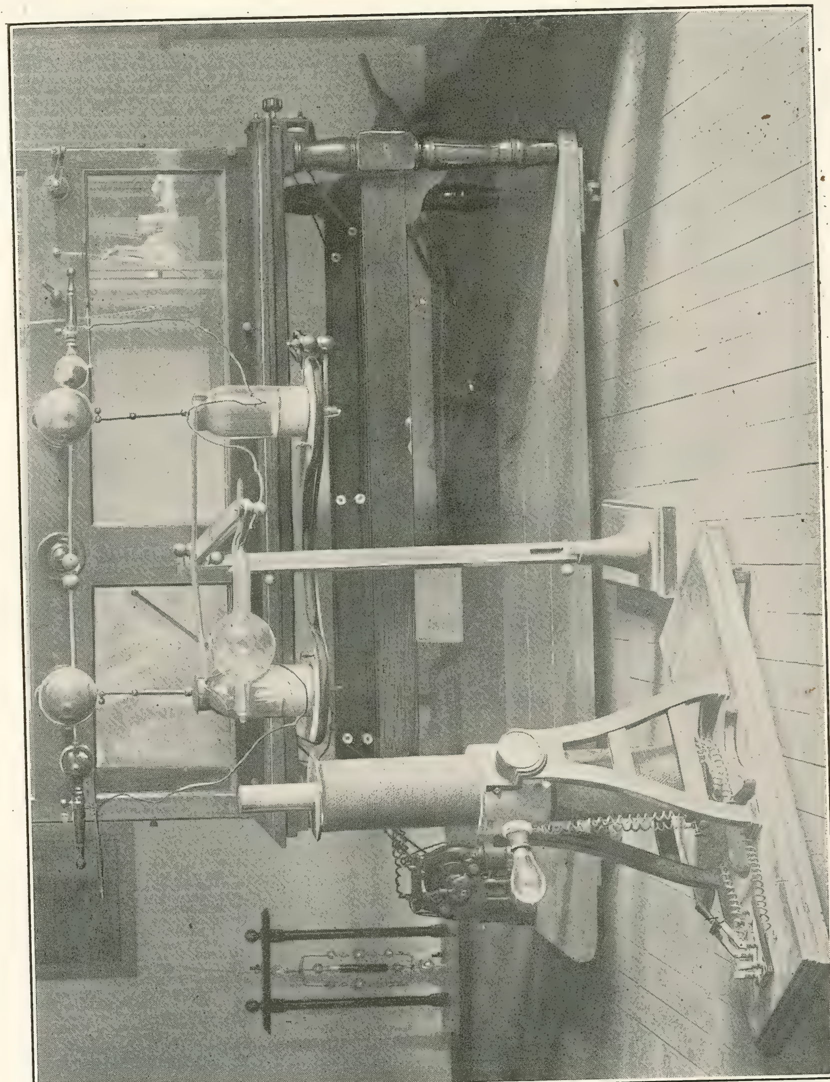


PLATE 24.—Combined Coil and Static Machine to Increase X-Radiance. See text for description.

can be highly excited with a current that would be far too little dosage for a large tube of the same relative resistance, because the moderate voltage will break down the resistance of the small tube, and the volume will be ample for the restricted area to be bombarded. But spread out over the surface of larger electrodes and of the glass of a large tube the volume of a small current makes too thin a bombardment to be effective, *i.e.*, it is too small a *dose* for the tube.

This explains why tubes must be adapted to the generator employed, whether coil or Static machine. A pony will not do all the work of a big horse, and a four-inch spark-current will not do all the work of a ten-, twelve-, or eighteen-inch spark-current.

But to set up an intense bombardment a current must have thickness, volume, and quantity as well as driving voltage-force. A long, thin spark is not evidence of a good apparatus. The spark must show fat proportions. It must be *thick*. In a coil this essential quality usually means more copper and more cost. In a Static machine it means more parallel revolving plates, and more cost also. Says a coil-maker, " By experiments I have found I can get as good, if not better, results with the fluoroscope, and take as good a picture with the same length of exposure, using the same tube in both experiments, with an eight-inch spark-coil with a No. 32 wire secondary, as I can with a twelve-inch spark-coil wound with a fine No. 36 secondary." The larger volume of the *coarser wire* lends more efficiency to a given voltage than the thin current of the thirty-six wire.

The same principle is demonstrated with the Static machine. Using the same tube and taking the same part of the body at the same distance and same exposure time, the maximum radiance developed by a Static machine with 300 square inches of generating surface was manifestly inferior to the negative produced by a machine with 512 square inches of generating surface. It is conclusively settled, then, that efficiency in any form of current requires a fat, thick, as well as high-potential discharge.

But, granted that apparatus supplies ample current, we must regulate it to some degree to suit the conditions of the work in hand. The objection to an under-dose is the obvious one that it will not do the work, but there are two objections to an over-dose which are hardly appreciated by operators. They are so important that it will be well to study them a moment. In the first place, the habitual use of too heavy a current " dose " for the tube tends to heat, increases the liability of puncture, raises the resistance, and shortens the life of the tube. Secondly, it is one of the chief factors in causing the irritative effects which are unfortunately known as X-ray burns.

However, with the more general introduction of recent regulating devices, the whole matter of dosage, formerly calling for much experience, will be simplified.

How to Test Tubes with a Static Machine.—Attach the connecting wires from the tube directly to the prime conductor of the Static machine, without Leyden jars or interrupters in the circuit. Darken the room, short-circuit the sliding poles, and start the revolving plates into action. When they attain an average speed gradually draw the poles apart, and note how long a spark-stream can be developed. The ball terminals of the sliding poles should always be brightly polished, as oxidation lessens the value of the test. One of three things will appear as the poles are very slowly drawn apart:

1. The spark-stream may attain a length of one, one and a half, or two inches, or a little more, and as the poles are drawn beyond this distance the spark will cease and the tube will suddenly glow with the proper green luminosity, and the fluoroscope will demonstrate X-rays.

2. The spark-stream may be less than one inch, or be any length down to the mere thickness of a sheet of paper between the poles, and in proportion as the spark is short the green glow will become dull, bluish, or slightly pinkish, or absent entirely; and when only very short sparks occur, the electrical discharge will form a visible bluish pencil directly between the two electrodes within the tube, instead of the invisible cathode cone. This denotes a lower vacuum, and if the discharge is decidedly pink the tube is too low for X-rays and requires exhaustion. If the discharge, in rare cases, passes between the anode and cathode unaltered from a similar discharge in the open air, it proves that the tube has entirely lost its vacuum. It may have lost it by puncture, or may never have been exhausted.

3. The poles may be drawn apart beyond the longest distance that any spark will pass between them, and the current may back up and leak from the connecting wires without going through the tube, which will remain dark, or occasionally a flicker may pass through it. This proves that the *resistance* at the moment is high, but it does not at once prove that the tube actually has a high *vacuum.*

If the immediate result is seen to be Number 1 the tube has a satisfactory vacuum, and is ready for work. It will require modifications of dosage and a proper regulation of the bombardment to vary its efficiency from minimum to maximum, and will not be actually operated under the conditions of the test. With a really large static current, generated by sixteen, twenty, or twenty-four revolving plates, thirty inches in diameter, and with the author's interrupters, almost any tube that tests up a resistance not lower than half an inch spark-gap can be worked with excellent efficiency.

If the result is Number 2 the resistance is too low, and it then becomes a question to decide whether it is a temporary state of the tube or a permanent condition of too low vacuum. If the tube is manipulated as directed under separate instructions on the management of tubes, the question can be determined in a moment, and the tube rejected or returned to the makers to be exhausted if the test shows this to be necessary.

If, however, the result is Number 3 the resistance for the moment is too high, but it is not yet proved that the tube actually possesses a high vacuum. If the indicated manipulation will not get the current through it, or if it can be lighted up momentarily, but will not hold, and if in the dark brush-discharges are seen backing up not only at the terminals, but all along the connecting wires, the vacuum is then determined to be too great for the electrical pressure. A resistance that would back up the current of a small eight- or ten-plate machine, would yield readily to the pressure from a machine double the size. In proportion as the operator possesses energy in the electrical discharge he loses trouble with the resistance of what, with small apparatus, appear to be high-vacuum tubes.

If the resistance can be reduced to a working point the tube will be satisfactory. This can be determined in about two minutes by manipulation. If it *remains* too high for the operator despite the above tests it may be rejected.

Note that the length of a static parallel spark-gap is very different from the coil. The higher E.M.F. of the static-current breaks down the gap quicker. A half-inch gap by static measure might be three or more inches by a coil. A three-inch static resistance would be a very much longer spark-gap with a coil.

The Travelling Focus.—Among the causes of blurred shadows due to movement or deviation from absolute steadiness somewhere in the field of operation, must be mentioned the shifting of the focus of the cathode bombardment upon the anode. This can be seen and usually corrected when it occurs.

It is caused by disturbance and irregularity in the electrical discharges. In a darkened room and with the anode below red heat the focus spot can be plainly seen. Adjust the dosage of current through the tube till the focus is visibly localized, and then observe it for a moment. If the voltage is excessive for the tube and the interruptions are not even and steady in character, the focus spot will often be seen to travel instead of remaining stationary. If it fluctuates around over the anode it will have the effect of a moving camera on a photograph, and sharp outlines will be impossible to secure. To correct the fault in the bombardment first correct the fault in the quality of the interruption of the current and adjust the electrical discharges to a smooth and even action. Beginners will entirely overlook this source of trouble till it is pointed out to them. Every operator should be alert to detect this shifting of the point of the cathode cone while tuning his tube for exposures, as no fine picture can be made with a travelling focus. See also remarks on augmentation of X-rays by an electro-magnet. This steadies the focus, as reported by Professor Gates.

Dosage of Current for Tube a Factor in Avoiding Dermatitis in X-Ray Therapy.—From careful consideration of effects and the general lack of regard to fine details of X-ray work, especially on the electrical side of the technic, it appears to the author that random dosage has much to do with effects which many writers perplexedly attribute to "the (mysterious?) condition of the tube." In my experience I have observed that there is a point at which the excitation of the tube is the nearest to what may be called for lack of a better phrase, a comfortable tolerance of the current. That is, the energy of the electrical bombardment and the resistance of the tube come the nearest to balancing each other. At this point the conditions around the tube are nearest normal, and there is no excess of discharge to spend itself harmfully upon the patient. With the Static machine this point of dosage can be regulated exactly, and also with all coils with means of full current control. The method is this: simply take a medium and efficient tube, excite it with a temporary excess of current, and then reduce the current till the anode loses its excess of redness. At the point when current and tube work easily and efficiently together with the anode just sufficiently but not too much heated, hold the current at the given dosage. Above all, do not put the tube too near the tissues.

Magnetic Augmentation of X-Radiance.—The accompanying picture of combined coil and Static machine was kindly furnished the author by Professor Elmer Gates, with the following account of his experiments:

"The interest which attaches to this experiment lies in the fact that the radiation can be rendered more steady, and the centre of incandescence on the anode can be confined strictly to that part of the metal where you desire it, and the luminosity is greatly increased. That the luminosity is very greatly augmented can be very clearly proved.

"I recently placed a powerful electro-magnet near one end of an X-ray tube, and found that when the magnet was excited it produced a very conspicuous increase of intensity of the X-rays. The bones of the hand could be distinctly seen through a fluoroscope at a much greater distance when the magnet was charged than when it was not. By interposing books between a key and the fluoroscope until the key was invisible, and then charging the magnet, I could easily distinguish the key with the augmented radiance. Old X-ray tubes which had become too high would operate with the assistance of the electro-magnet.

"I used a ten-plate thirty-two inch Static machine, and when running at full capacity it keeps the platinum in the tube slightly red-hot at the focus point. When the magnet is charged this platinum electrode immediately becomes glowingly incandescent. In working with this Static machine and with the same tubes none of us had ever before been burned, it being perfectly safe to expose any part for two or three hours to the action of the X-rays. But when this electro-magnetic experiment was made we all felt a decided irritation of the skin of our hands and faces after six or eight minutes' exposure. The core of the magnet used is thirty-six inches long, two inches in diameter, and takes a current of 110 volts and twelve amperes. Effects were noticeable with a weak magnet, but were not conspicuous until I used a powerful coil. The apple-green luminosity of the tube is increased four or five times, possibly ten times, when the current is on the coil. The core of the coil is placed somewhat nearer the anodes than is shown in the picture.

"On the same day I studied the effect of the magnet on the stratification phenomenon of a Geisler tube. I have a long Geisler tube which, with my machine, gives a stratified appearance of waves at least three-fourths of an inch long; but when the core of the magnetized coil is close to the tube these waves become about one-eighth of an inch long, or even shorter, and the rate is correspondingly increased.

"The electro-magnet has a good effect in steadying the bombardment within the tube, holding the cathode-stream so that it does not shift its focus, which is an important matter. It may be that this method will shorten X-ray exposures, and serve to prevent the flickering which often blurs the image.

"While demonstrating the phenomenon to an electrical expert from the Patent Office, I noticed that I could get the apple-green radiation at great intensity with one position of the magnet, and by a little change in its position and distance from the machine I got an entire absence of the apple-green radiation, and in its place a most intense purely violet radiation from the anode."

CHAPTER XI

STUDIES IN FLUOROSCOPIC TECHNICS

The Fluoroscope. Studies of its Utility in Practice. Selection and Care of the Instrument. Correct Fluoroscopy. Exact Technics. Open Fluorescing Screen. Darkening the X-Ray Operating-Room. Darkening Tube Devices. Light Screen. The Stereoscopic Fluoroscope. The See-Hear. A Fluorescing Garment. Measuring Stand. The Skiameter. How to Outline X-Ray Shadows on Tracing Paper. Author's Heart Outliner.

The Fluoroscope.—Differing somewhat in the shape and size of its box and in the quality of its screen, the fluoroscope has been more or less indifferently used, and opinions of its value have been variously expressed. It will be educational to note a few of them before considering technique:

" Edison took advantage of the hint given by Professor Roentgen and devised the *fluoroscope,* and in so doing gave to the world one of the most important adjuncts to the X-rays themselves. Much has been written of the photographic applications of X-rays, but the fluoroscope has not received the attention its importance deserves. With this device we have a speedy means of approximately locating opaque foreign bodies in any region of the human economy if our apparatus is but sufficiently powerful to excite the tube to the necessary degree. Instead of being limited to the single view of a skiagraph we may examine our patient in any position, determine with great certainty the presence and nearly the position of bullet, needle, metal, or glass and gain considerable intelligence before operating. Obscure fractures and dislocations are determined, even though the œdema of the soft parts is so great as to prevent an exact diagnosis by other methods. Exostosis or congenital malformations can be detected at once, and their removal or correction facilitated. Beyond its aid in diagnosis the fluoroscope is a well-nigh indispensable aid in operating, for by covering the instrument with a sterilized towel we can *watch the steps of the operation* in removing foreign bodies or verify their absence. Indeed, if the object cannot be readily found, and we all are aware

how elusive needles and shot can be, we can follow our instruments as they penetrate the tissues and observe their proximity to the body sought.

" As a means of medical diagnosis . . . dependent upon their location . . . some of the denser tumors cast darker shadows than the surrounding tissues. Tubercular or syphilitic osteitis is revealed, showing either the rarefied areas incident to the disease, or the blurred and irregular outline of the bones, a lack of the usual clear-cut, well-defined shadows. In the examination of the thorax . . . the fluoroscope is of infinite service, as also in the detection of fractures of the ribs. A few cases will illustrate the surgical adaptability of this convenient instrument:

" Mr. F. A case of suspected rheumatism. Fluoroscope revealed small bullet in the knee-joint.

" Mr. B. Was shot in left foot and great toe amputated. Discharging sinus persisted instead of foot healing. Fluoroscope revealed fracture of second and third metatarsal bones and five remaining shot.

" Mr. S. Was shot in elbow and bullet supposed to be imbedded. Fluoroscope proved its absence. None of the delay of a radiograph required.

" Mr. K. Tumor in lower third of femur. Fluoroscope revealed bone shading off into tumor. Diagnosis, Osteo-sarcoma. Amputated at hip-joint. Microscope verified diagnosis.

" W. H. Fluoroscope revealed old backward dislocation of radius and ulna, fracture of olecranon, and joint capsule filled with adhesions. Operated.

" Mr. M. Right hand pinched in coupling cars. Cellulitis and swelling so great as to prevent diagnosis of condition of bones. Fluoroscope revealed fracture of third metacarpal bone at middle of shaft, and partial crush of head of the bone.

" M. S., age seven. Hand puffed badly; last two fingers flexed and numb. Two weeks previous the child ran a needle into the palm of her hand and it broke off. Fluoroscope revealed it, and incising with instruments under the fluoroscope, it was quickly removed.

" Child, sixteen months old. Five days previous swallowed safety-pin. Fluoroscope showed the pin in ascending colon, open, but pointing the right way. Refused to operate, holding that if it had gone so far it would go farther. It was passed the next day.

" G. C. D. Chip of steel imbedded in the heavy muscles of calf. Physician enlarged entrance but failed to find chip. Fluoroscope revealed it at once, and under it I introduced forceps into the wound, watched them grasp the piece of steel, and removed same promptly.

" Mrs. R. Fluoroscope revealed sarcoma of right shoulder so extensive as to advise against operation.

" Miss S. Needle in hand. Removed under fluoroscope.

" Operations in three of these cases were done with the room perfectly dark, simply using the fluoroscope as a guide. The fluoroscope also supplies knowledge as to whether a radiograph is needed or not. While great proficiency in reading its shadows is a matter of some experience, yet even a novice can diagnose many cases with it." (LAW.)

"Boy, five years old, emaciated, nervous, pain after eating, with several small hemorrhages in past three weeks; profuse hemorrhage day previous; poor appetite and afraid to eat on account of pain. Seventeen months previous had swallowed book-case key. Gave no trouble for twelve months but now threatened life. Fluoroscope readily revealed the key. Later introduced spiral forceps into œsophagus under anæsthetic. With fluoroscope over stomach found forceps were two inches too short. Shifted table, bringing head down, and, by manipulations with hand on abdomen, finally moved key up to forceps and engaged it. At length withdrew it, after which a free hemorrhage followed. Under careful treatment boy recovered. The fluoroscope was the means of success in directing the key. The recovered key was three inches long and so corroded that the handle was no thicker than a sheet of paper. The tongue was nearly rusted off. The extremity made sharp, ragged edges. Had the key remained it would have soon killed the child, either from inanition or inflammation, or from recurring hemorrhages, as the sharp points would have increased in number by corrosion." (ARP.)

"The fluoroscope is an accurate agent for corroborating and extending diagnosis made by the ordinary methods. It is capable of demonstrating foci of tubercular infection earlier than they can be distinguished by the ear. It shows either unilateral or bilateral enlargement of the heart and all displacements of that organ. Emphysema, asthma, pleurisy, hydropneumothorax, hydrothorax, and pneumonia, are all easily recognized and their limits demonstrated. In pneumonia it has been claimed that a more certain prognosis may be assured by the use of the fluoroscope. Thoracic aneurisms are recognizable in their early stages. Considerable practice is necessary before the eye can appreciate perfectly the fine differences of shade and outline." (STUBBERT.)

"In pleuritic effusions the fluoroscope shows the displacement of the liquid as the patient assumes different positions, and with the action of the diaphragm. Purulent effusions seem less opaque than serous, but its principal value consists in the information it affords as to the condition of the lungs above the effusion. It reveals bacillary lesions and has a great prognostic value." (BERGONIE.)

"The fluoroscope gives a better assurance that the lungs are in a healthy condition than other methods. It gives earlier evidence of lung disease and more accurate information concerning its extent. The heart may be outlined more accurately than has been hitherto possible." (WILLIAMS.)

"For a preliminary and superficial examination the fluoroscope is indeed invaluable. For examining those organs which should be studied while in motion—for instance, for observing the mechanism

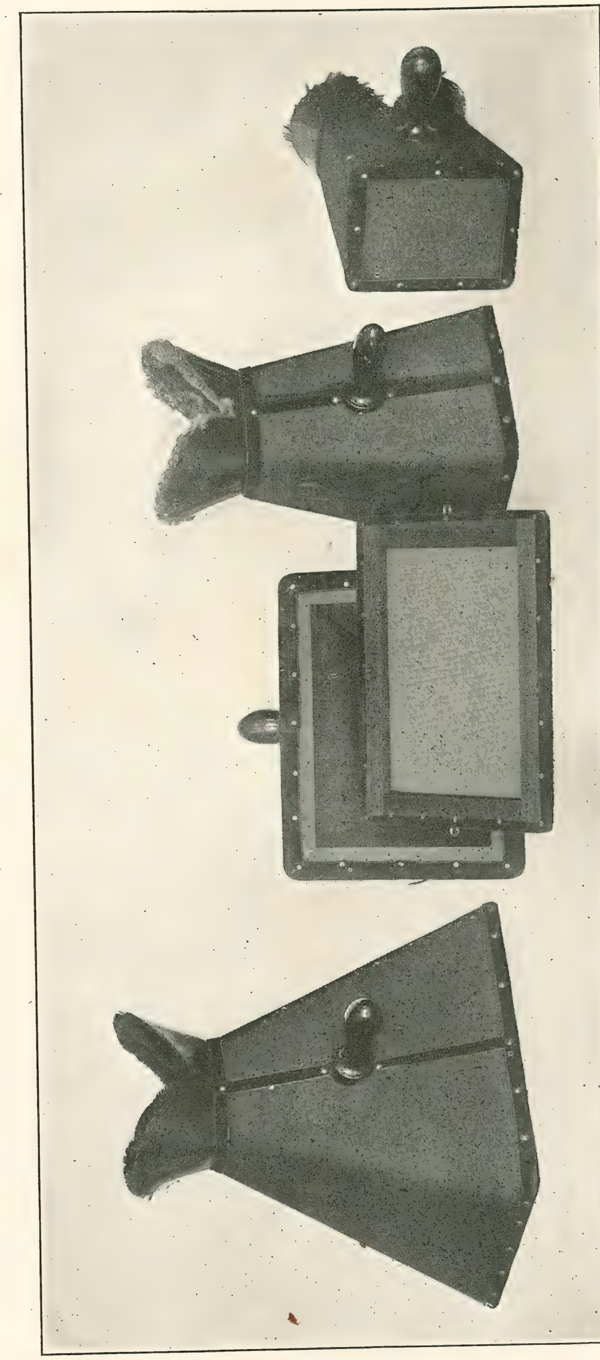


PLATE 25.—Showing practical sizes of Fluoroscopes for regular use. One shows the removable screen detached. The screen can be used without the box when desired, and the box can be separately used for the examination of negatives as described in section on reading negatives. The set here pictured show the four sizes belonging to the author.

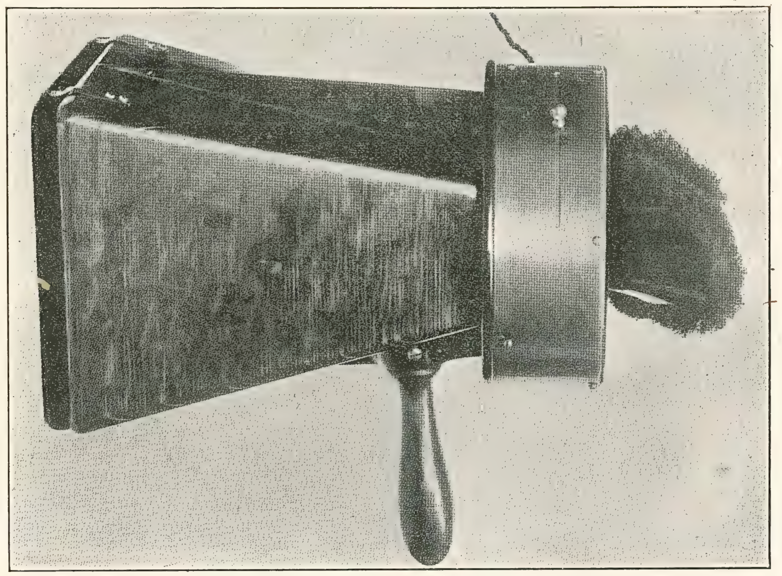


PLATE 26.—Showing a projected Stereo-fluoroscope with rotating shutter operated by small independent motor. It aims to improve upon the earlier pattern of Davidson, which was not freely movable. At least three ingenious workers are busy at the problem of a practical Stereo-fluoroscope, and it is probable that in the near future this much-needed instrument will be born.

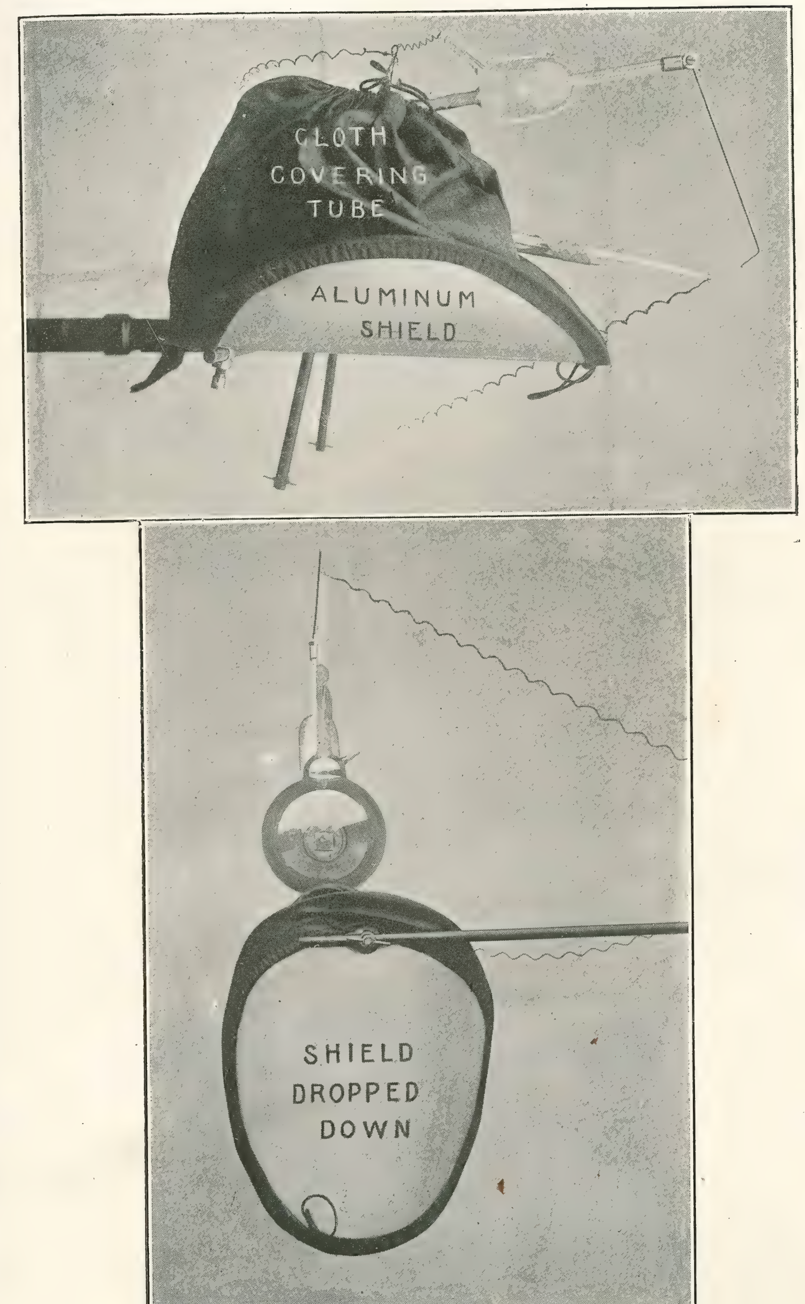


PLATE 27.—This plate makes clear the device suggested by Dr. Pfahler for darkening the tube. In the upper figure the main bulb of the tube is within the hood, and in action throws the rays down or out through the aluminum shield. The small auxiliary bulb seen out of the hood is the vacuum regulator. In the lower figure the hood is dropped to expose the tube.

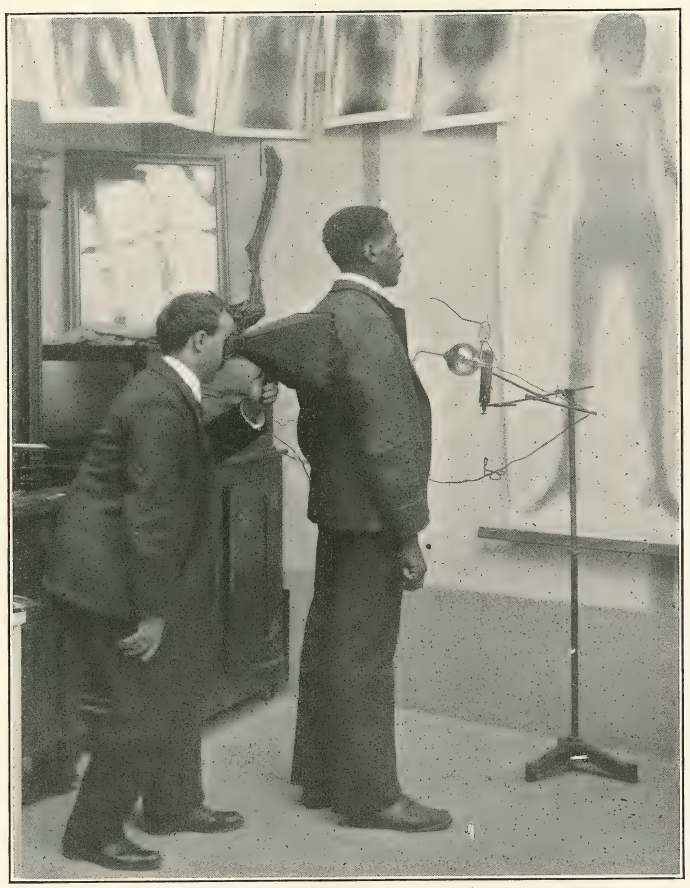


PLATE 28.—Fluoroscopic Technics. This Instruction Plate shows the casual method of inspection in common use. Do not expect to determine a fine diagnosis of obscure thoracic conditions with the patient fully clothed and by the off-hand glance made in haste by rapidly turning the man around. In this way there is no adjustment of the axis of the rays, or the distance of the tube, and the position of the screen, except such as result from guesswork. Note also that with the arm down and the fluoroscope as placed in the plate the scapula casts a dark shadow over the lung tissue and prevents clear examination of the area. The relative positions of tube, patient, and screen in this picture are, however, much nearer correct than many employed in general practice.

of joints, the thoracic organs—fluoroscopy is the reigning method. But the fluorescing impressions, succeeding each other rapidly, are apt to blur in the eye if the features of the lesion are not distinctly marked, while fixation on a photographic plate gives all the details exactly. Therefore the fluoroscope should be used in fractures as a preliminary procedure only. It calls attention to the seat of the fracture, and determines the best position of the limb for the photographic posture. Especially in joint-fractures it will select the angle of flexion in which the injured portion can be brought out best on the plate." (BECK.)

The flexibility of the fluoroscope as an examining instrument is beautifully illustrated by a case of Dunn's. A six-year-old girl had swallowed a brass rivet seven months before. The physician believed the rivet had passed into the stomach and had caused no harm, but when brought to the surgeon the child was unable to swallow anything except liquids, and was almost in a moribund condition. The mind can hardly conceive of attempting to trace the rivet in the human body and to locate the proper place for a surgical incision before the discovery of X-rays. What took place with X-rays was as follows: "I placed the patient in front of the tube and with my fluoroscope I searched the stomach and the intestines for the rivet. At a glance I could see that it was not there. Passing from the abdominal region up over the thorax with the fluoroscope, I could see nothing but heart, liver, ribs, and spine until I reached the cervical region; there I saw the rivet lying behind the larynx. Placing my hand upon the neck immediately over the rivet, and making alternate pressure from side to side, I could *see* the rivet gliding under my finger between the larynx and the cervical vertebræ."

These early observations of the function and value of the fluoroscope have passed into accepted truisms.

With the true expert there can be no controversy between the function of the fluoroscope and radiograph, nor will he be in doubt as to when to use one or the other, or both. Some writers of less wide experience have asserted that the fluoroscope was nearly useless save for observing a tube and that all practical work should be done with the negative. On the other hand, equally narrow observers have repudiated the radiograph and declared that the fluoroscope would eventually be the sole instrument employed. Neither of these views is correct. A photographic plate and a fluoroscope are by no means interchangeable instruments for diagnostic examinations, and the place of each is as clearly defined in practical work as percussion and auscultation. The following communication will, however, be instructive to the beginner, as setting forth a practical argument which too many workers overlook:

"Dr. ——— says that *at least two* skiagraphs of suspected fractures should be taken, or the fracture may not be apparent. But even this may be insufficient. Four good, clear skiagraphs were taken of an imperfectly united tibia, before the line of separation, due to a band of fibrous tissue, was evident. A boy exhibited signs of recent fracture of the tibia. On fluoroscopic examination, a long, oblique fracture was visible, but only when the leg and tube were held in just a certain position. A deflection of ten degrees in any direction completely hid the line of separation from view. Apparently the periosteum, intact in places, held the fragments close together. In most fractures that have come under our observation, the fluoroscope is better as a means of diagnosis than the plate. The relative position of tube, patient, and fluoroscope can be easily and rapidly changed, securing in ten minutes a view from every possible angle, an absolute necessity in some cases, as in those cited above. It is impossible to say off-hand which angle will show the condition the best, and an experienced fluoroscopist can derive fresh information from every position of the tube. To secure the same thoroughness by plates would require hours instead of minutes, and dollars instead of cents. Bone being so much denser than the surrounding structures, the superior delicacy of the plate is usually not needed, excepting about the pelvis. In these and a few other cases skiagraphs are necessary, but in ninety-nine out of a hundred fractures the fluoroscope not only is easier, quicker, and cheaper than the plate, but it gives far more definite information." (Dr. R——.)

Selection and Care.—The box of the fluoroscope is usually a rigid frame, but some have been made with collapsible sides. For ordinary office use the rigid box is preferable. But it should be light, neat, and workman-like. A clumsy, rudely made box is not so satisfactory to the hand employing it. The screen in its frame is now made detachable from the rest of the box when desired. The combination of box and detachable screen affords the widest range of usefulness to the instrument.

In general practice the surgeon should have two sizes; a small one for the critical examination of very small areas from which it is desirable to exclude all surrounding fluorescence from the eyes, and one of medium size for every other use. Very large screens may occasionally serve a special purpose but will rarely be required in private practice. Some have been made as large as the human body.

At the present time all fine fluoroscopes have screens of platinocyanide of barium, which yield a much greater detail of definition than was furnished by tungstate of calcium. The best quality of these screens shows little tendency to deteriorate with time. Improved

processes of manufacture have conquered many of the difficulties of earlier days and now provide us with a beautiful and reliable instrument.

Part of the excellent preservation of fluoroscopes will depend on the care given them by the surgeon. When not in use a soft cloth or tissue-paper should be stuffed in the top to keep out all floating dust, and they should be kept in a dark closet without dampness. If exposed to dampness during a wet season the backing (vellum or cardboard) of the screen will warp, and in shrinking again will in time injure the coating. Avoid this by a uniform dryness.

Correct Fluoroscopy.—Let us now abandon the careless use of the fluoroscope and begin the practice of accurate methods. The essentials of correct observation by means of this instrument are:

1. The observer's eyes must be closely pressed within the opening of the fluoroscope so as to exclude all external light, and the retina must be allowed time to alter from normal to a state adapted to the dark.

2. The base of the fluoroscope must be firmly pressed to the closest possible contact with the part to be examined.

3. The fluoroscope, the patient, and the active tube must be so placed in relation to each other that a straight line drawn through the part and to the focus point of the X-rays will make a perpendicular with the base of the screen at its centre. The parts will then show without distortion of the shadows.

4. The current exciting the tube must be adjusted to give the degree of X-radiance needed for the particular purpose of the examination.

5. The density and relation of the shadows must be systematically shifted till the eye best catches what it looks for in the case. This is usually done by altering the distance between the patient and the tube so that the penetration required is found by preliminary tests, and the examination is then completed at this distance. With the left hand press the part toward the screen while pressure against the screen keeps it firmly in contact with the tissues, so that in all tests of distance the operator, fluoroscope, and patient will preserve a unity of movement coinciding with the axis of the rays. When this is done the eye deals with right-angled shadows and not with the random distortions which have caused so much distrust of X-rays.

Do not tilt the fluoroscope up or down, or to the right or left. Do not let it move from the field of the rays to which it has been adjusted without also squaring the base of the fluoroscope with the axis of the new field. Neglect of this is the cause of most of the distortion that occurs in these examinations. Refer to your Divergence Chart and note how a true relation of parts can be obtained at any arc of the hemisphere of radiance provided that the plane of the screen is turned to the line of the central ray so as to form a right-angle with it.

The main uses of the fluoroscope are:

1. To enable us to make observations upon the actions of tubes, either for testing them or to watch their working during an exposure of a plate.

2. To enable us to obtain preliminary knowledge as to the need of a radiograph and the field of exposure.

3. Such general purposes of diagnostic examinations as come within its scope as set forth in these chapters.

4. To not only detect but to approximately locate foreign bodies when these are opaque to the rays and so situated that the eye can see them on the screen. Localization is treated of under its proper head, and the important matter of so-called "X-ray fallacies" will be considered in our study of "distortion."

The researches of a French scientist show that there is an enormous difference between a normal retina and a retina not adapted to fluoroscopic work. They also show the almost incredible increase of sensibility obtained by a few minutes closure in a dark room preparatory to examinations. Ten minutes thus spent increases the retinal sensibility from fifty to a hundred fold. Twenty minutes in a dark rooom increases the sensibility nearly 200 times as compared with bright daylight. But the ability to distinguish form and detail is less. However luminous the fluorescing screen may be it is inferior to full light, and hence the eye cannot derive from the increase in sensibility an advantage equal to its loss of visual activity in observing shadows under the conditions of fluoroscopic work.

The photographic film is not subject to this drawback and its impressions are cumulative, hence in respect to definition its capabilities are greater than those of the eye can ever be. The capacity of the normal eye under favorable conditions is proportioned to the opulence and steadiness of the X-ray discharge, and the mere quality of *penetration* without richness of quantity does not supply the eye with what it needs for diagnostic examinations.

The conditions required for the highest degree of visual activity and retinal sensitiveness combined are:

1. A heavy exciting current.

2. An interrupter that works the tube without flickering of the light.

3. An opulent generation of rays. (Rich in quantity.)

4. The exclusion of all other light from the eyes.

5. A high-class fluoroscope giving fine definition.

6. A tube that focuses correctly for sharp shadows.

Without a proper tube the best of fluoroscopes is at a disadvantage. To lessen time needed to alter eyes for fine fluoroscopy in dark room wear smoked spectacles during the last ten minutes of preliminary work if convenient to do so.

The Open Fluorescing Screen.—It has been claimed that in making long visual examinations (or many of them) the use of the regulation pyramidal box to exclude the light is fatiguing to the eyes because they then work in a confined and warm atmosphere at an arbitrary accommodation, and are required frequently to adjust themselves to variations in the light caused by removing the fluoroscope at intervals and resuming it again. This strain is greatest when the examinations are being made in daylight or an undarkened room. Moreover, all eyes do not focus at the depth of the box, and hence the arbitrary distance is another cause of strain. The box also is an inconvenience in the process of tracing records of the heart, movements of the diaphragm, and local shadows anywhere. Yet the boxed fluoroscope is an indispensable instrument in its entirety, and possesses advantages for which there is no substitute.

On the other hand, an *open* screen has certain advantages for selected kinds of work, and permits every eye to focus at its preferred distance from the shadow to be examined. It offers facility for tracing shadows which the box bars, but as it does not supply its own darkness it cannot be well used in a light room. Yet, as both the complete box and the separate screen have important uses, they should both be supplied in the one instrument. This has been done at the author's suggestion since the summer of 1898 by the maker of the original Edison fluoroscope, the framed screen of which is removable from the box at will by a set of hooks and eyes.

Specialists whose work falls in a routine line and who wish only the screen, can have one of preferred size framed and mounted on a standard adjustable to various positions. Such a mounted screen is shown in the illustration of the "skiameter" kindly furnished by Dr. Crane.

Darkening the X-Ray Operating-Room.—While the American fluoroscope is admirably designed to enable the operator to examine patients in ordinary light, yet no worker will fail to desire a means of making the room dark *at any time he wishes.* Not only are there certain advantages in a large unmounted screen, especially when tracings are desired, but many reasons make the command of darkness a necessity. Wooden shutters and holland shades have drawbacks. The best method is to fit black felt light-proof curtains on a frame larger than the window, and rolling up and down in a U-shaped groove so as to exclude all stray rays. Without this convenience of artificial darkness at command, it will be almost impossible to do general X-ray work with satisfaction. Few operators realize the difference between using the fluoroscope casually with no reference to the effect of light upon the eye, and using it with systematic care to adapt the eye to the slightest deviation from total darkness. The eye turning to the fluorescing screen from a bright light will see only the major contrasts; eyes dilated by preparation in the dark will take in details with much greater amplitude.

If for any reason shades are not feasible the operator may then construct an interior "dark-tent" around his apparatus, and shut out the light from a part of his office in the following manner. Secure firmly to the floor at each corner of the space required by the coil and patient an upright post seven feet high. Frame them at the top by cross-bars. Cover the sides and roof with light-proof black cloth, leaving a curtained entrance in front. A small office is usually darkened without much difficulty, but there still remains for consideration in fine work the exclusion of the local luminosity from the Crookes tube. There are various ways of treating this.

Black Varnish for Tube.—With a suitable brush paint a rather thick coat of black asphaltum varnish over all the glass surface of a selected tube except an observation space in the unlighted back half of the bulb. It will require some care to lay the varnish smoothly over the area fronting the focus, so that when lit up it will not let light through in streaks. For three years one of my early tubes did its work within a coat of this varnish. It did not lessen its efficiency in the least. The varnish did not interfere with either penetration or definition, and is readily applied by anyone.

A student finally broke this fine tube by touching it with a heavy gold ring while it was in action.

Box-Covered Tube-Holder.—Instead of simply throwing a black-silk sheet over the patient and tube and the examiner's head, something as a photographer covers his head and camera, the tube can be inclosed in a box which will exclude either all luminous effects or let light only through the small opening of a diaphragm. This box idea is incorporated in a tube-holder made by an Eastern manufacturer of X-ray apparatus.

Dark Chamber for Tube and Shield for Prevention of X-Ray Burns.—"For some time past the interposition of an aluminum shield grounded by a wire to the gas- or water-pipe, has been recommended. I wish here to present briefly a simple and convenient method of applying this principle, which may be of interest to those doing much work in this line. This method with a little modification can be applied to any form of tube-holder.

"It consists of a shield made from a sheet of the thinnest aluminum, cut circular, ten inches in diameter, the cost of which is trifling. A hole one-half inch in diameter is cut about an inch from the edge, and passed over the clamp that grasps the horizontal arm of the stand. The washer, having been filed sufficiently to allow for the thickness of the aluminum, is replaced and the shield fastened in the upright position in front of the tube. The shield may be bent about the tube, as seen in the Instruction Plate No. 27.

"It will now keep its relative position no matter how the tube is adjusted, and needs no further attention from the operator. Being attached to metal the stand itself needs only to be grounded. The shield will thus always be in use to protect the patient.

"Should it be desired to use the tube for therapeutic purposes, the thumb-screw is loosened and the shield allowed to drop downward, which only requires a few seconds.

"For class demonstrations the mounted fluorescent screen offers advantages over the fluoroscope, as it enables a number to see the same object at the same time, and thus permits the demonstrator to point out the interpretation of the different shadows. Its use, however, requires a dark room. In addition, the luminosity of the tube may be excluded by attaching a piece of thin, very tight mesh black silk to the edge of the shield, and bagging it over the tube by means of a draw-string. The whole arrangement is so simple, convenient, and inexpensive that I present it to the profession with the hope that it will give others equal satisfaction." (PFAHLER.)

Rubber Jacket.—Another device for protecting the operator's eyes from the luminosity of the tube has been mentioned by Price, as follows:

"I must speak here of one addition I have made to tubes which is different from anything I have seen or heard of. It is for screening all luminous rays from the tube, while allowing the X-rays to pass. It consists of a jacket of unvulcanized dental rubber. I use the red rubber (which is opaque to the X-rays) for all parts except where the rays are emitted, where I use a window of black rubber, through which the X-rays pass unobstructed. This jacketed tube is then adapted for making fluoroscopic examinations in total darkness. It works to perfection."

Operators whose work does not require them to darken the tube except on rare occasions will find it a simple and useful device to throw a small square of thin black silk over the tube, when desired. The attraction of the current will hold it in close contact with the tube. It may be thrown on and snatched off at will while the tube is in action without a second's delay. The box inclosing the tube, the diaphragm, a coat of black varnish on the tube, the silk bag, and the loose square of silk as above mentioned, as well as the rubber jacket, are all efficient means of excluding the phosphorescence of the

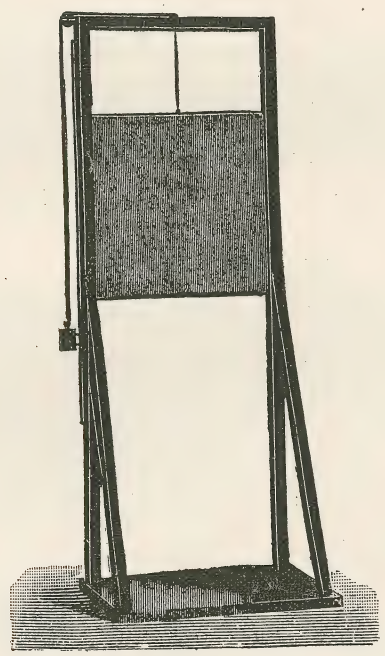


FIG. 9.—Sliding screen to shield eyes from light of tube in fluoroscopic work. The weight on the cord balances the screen at any point wished. Simply stand the frame on the floor in front of the tube, raise the screen to hide the light and pose the patient in front of the screen.

tube-wall, which must be kept out of the eye for the finest fluoroscopic work.

Light Screen for Continuous Fluoroscopy.—Make two upright posts five feet high and nail them on a base-board two feet apart, with a cross-bar at the top. Projecting backward from the top nail two light strips of wood a foot long, and complete them with a strip across their ends. Tack between the strips and posts of this frame a sheet of black paper similar to the inside envelope-wrapper of X-ray plates and the device is ready for use. If the base-board is made so that the patient stands or sits on it during the examination the frame will stand securely without risk of being pressed back upon the tube.

A variation in construction can be made. Between the posts fit a thin sheet of vulcanite, such as is used over the front of a plate-holder, in a frame which will slide up and down as desired. Balance this with a counterpoise weight. It cuts out the light in the direct path from the eyes to the tube when arranged at the proper level.

In practice simply place the frame between the patient and tube and as near the tube as the current will permit. The first design will cut out light from the top as well as from the direct path, and shields the eyes to a much greater extent than the smaller screen. It can be made at home for a few cents and a little trouble, and for one who makes regular use of the fluoroscope, as, for instance, in pulmonary examinations, it will be found invaluable.

The Stereoscopic Fluoroscope consists of a fluorescent screen illuminated by two tubes which are lighted alternately. A rotating disc with appropriately placed slots eclipses each eye alternately. This works synchronously with the action of the tubes. Each eye sees the shadow cast by one tube. A stereoscopic image is thus cast on the screen, the movements of the shutter being sufficiently rapid to give a continuous illumination of the screen. The general localization of a foreign body is thus greatly simplified and the nature of a fracture can be seen at once.

Several inventive operators have devoted much time and thought to the improvement of this device to a practical and easily worked convenience. With a perfected instrument of this kind almost all that has been written of X-ray fallacies, and many theories as to the medico-legal status of X-rays would lose weight, for the convincing view of a body stereoscopically seen by the eye is altogether a different matter from a shadow without thickness.

The importance of a readily operated stereoscopic-fluoroscope cannot well be over-estimated. Only a trained expert can grasp the full significance of such an instrument in practice. One of the difficulties has been to get two tubes that would work equally. The fine regulating devices entering the market as this is written ought to facilitate the working of the now all but practical stereo-fluoroscope. It is a great mark for coming X-ray inventors. *No other one instrument will give such value to Roentgen's discovery, for it will carry binocular vision directly into the tissues which now only appear on the screen in a plane shadow. The achievement of the third dimension will entirely revolutionize X-ray diagnosis.* With this too brief mention we leave a great subject to the developments of the near future.

The "See-Hear."—A combination stethoscope-fluoroscope is called the see-hear. It is designed so that while the ear is ausculting the heart or lungs the eye may be inspecting the same regions. The originator's remarks are as follows:

"The instrument contained two principles new in stethoscopes; one a sound chamber, the other a fluorescent screen in connection with a sound chamber. The former has since been adopted in one of the stethoscopes in common use. The latter awaits recognition. As shown in the figure, the fluorescent screen is about seven centimetres in diameter. The sound chamber is one centimetre in depth, the wall toward the patient being of thin hard rubber or other radiable material. There certainly is an advantage in hearing the sounds in the chest while the organs are under inspection, and, as I have designed comparatively cheap apparatus, giving plenty of X-light of suitable quality, such an instrument as the see-hear should be used extensively. Perhaps in the form now shown it may be appreciated."

FIG. 10.—The See-Hear. One form of combined fluoroscope and stethoscope enabling the operator to see the movements of the heart while listening to its sounds. Another form makes use of an open mounted screen with a sound chamber added to the fluorescing base.

A Fluorescing Garment.—We find the following note in a medical journal: "Von Ziemssen, improving on the method of direct examination by means of the fluoroscope, clothed the patient in a closely fitting covering impregnated with a fluorescent compound. In this way, the position and movements of the viscera can be comfortably observed."

A Measuring Stand and Examining Frame.—To aid in measuring the position and sides of internal parts or foreign bodies, the measuring stand of Hoffmann consists of a square frame which can be moved up and down between two posts. These upright supports are connected at the top by a cross-bar, and are mounted on a substantial platform upon which the subject stands or is seated on a stool. The weight of the patient thus anchors the apparatus firmly on the floor.

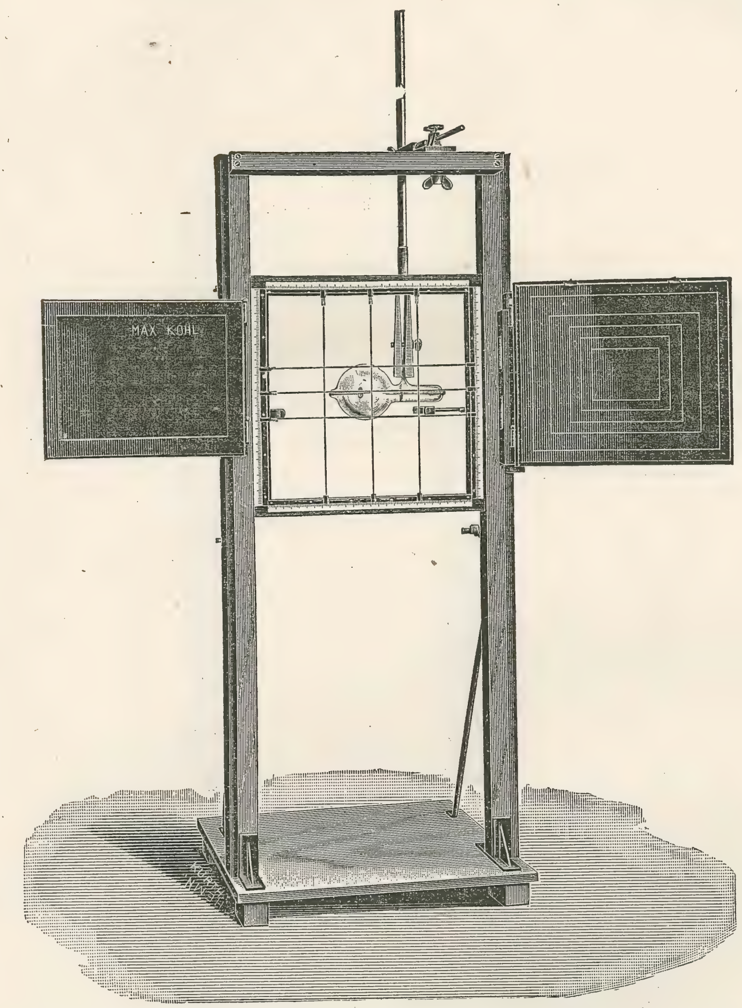


FIG. 11.—Measuring Stand for X-Ray Examinations Designed by Dr. Hoffmann. The patient sits behind the wires and the operator views from the front. At the left is seen the mounted screen to swing round in front of the patient. On the right is a plate-holder for making a radiograph of the part after the fluoroscopic inspection.

"The movable frame is mounted with brass side-pieces and is adjustable to any height of the stand. The movable frame is then fitted with three vertical and three horizontal metal cross-bars like stout knitting-needles. These are also movable, and the edges of the

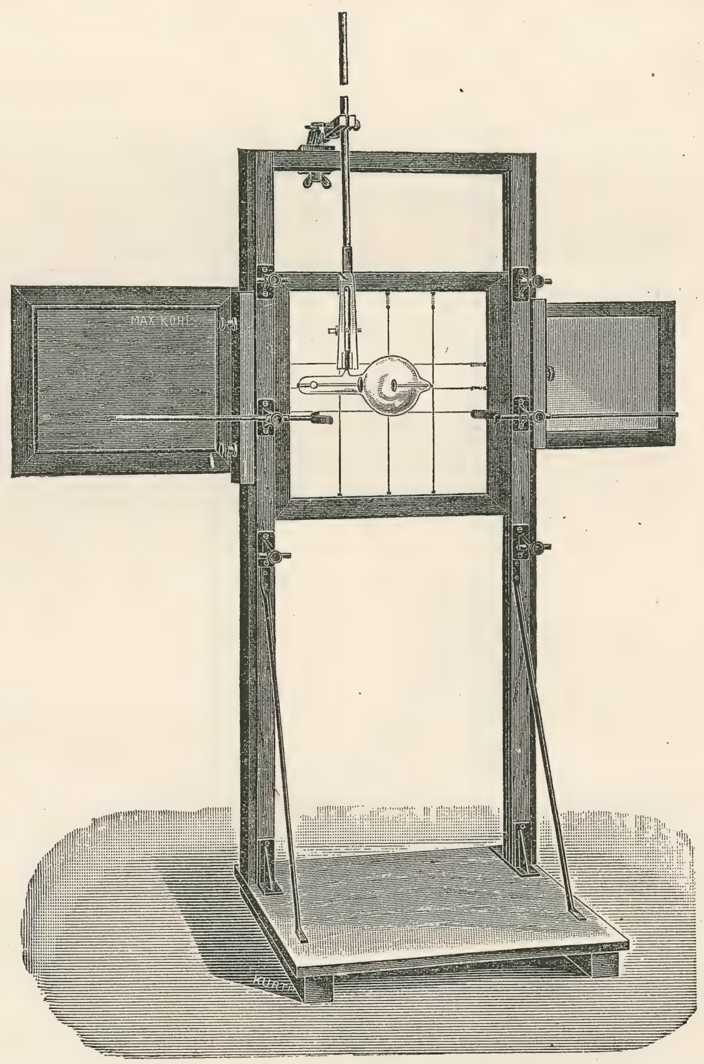


FIG. 12.—Back view of Dr. Hoffmann's measuring stand for X-ray examinations.

frame are marked with a millimetre scale so that the distance separating the parallel wires can be read. One of the upright posts of the stand is provided with three rests similar to the head-rest used by photographers to aid in holding the patient in position. At the sides of the stand are two accessory frames on hinges, one for receiving a

plate if a radiograph is to be made and the other to hold the fluorescent screen if visual inspection is desired. Operators using the American fluoroscope may detach the screen from the box and use it with this stand, or they may use the fluoroscope in the usual manner. The cross-bar at the top of the stand carries a tube-holder with an adjustable arm, which permits the tube to be placed at any desired height or position.

"For practical use seat the patient in the required position on the base of the stand. Adjust the measuring frame to the height of the field of the part to be examined; for instance, the thorax; adjust the tube at the desired level two feet distant from the centre of the movable frame. Insert the fluorescent screen in the frame designed to hold it, and swing it on its hinges around against the cross wires. When ready for the examination start the tube into action, have the patient press closely up in contact with the frame and screen, and proceed in the usual manner. Both hands are at liberty, and the cross wires may be set at any desired point.

"It is obvious that by approaching two horizontal rods and two vertical rods to the margin of shadow that an organ, the heart, for instance, can be practically framed. If a third wire is first fixed as a landmark in relation to a definite point on the patient, as, for instance, the nipple, the position and size of the heart is practically mapped out and can be read upon the millimetre scale. The same principle can be employed upon a radiograph. A bullet or small object can be made to register at the angle of two cross-bars. The skilled operator will, of course, take into account the thickness of the patient, the distance of the object examined from the screen, and the enlargement of the shadow caused by the divergence of the rays."

The illustration of this apparatus shows the tube-holder attached to the cross-bar of the stand. This necessitates a new adjustment of the tube for every movement of the wired frame. A great improvement would be made by attaching the arm supporting the tube to the top of the movable frame, so that when once adjusted it would follow each alteration of the field automatically. As this is a useful device, the American physician who has one made to order may wisely modify the construction as above suggested. See also description of the author's localizer and examining frame.

The Skiameter.—This word has been applied to three different devices by different X-ray writers. It indicates a "shadow-measure," and has been taken out of the commonplace and lifted to scientific eminence by the labors of Dr. A. W. Crane, whose classical account of his instrument and its uses will now follow:

"The essential idea of a means of mensuration by which we may increase the delicacy of our observations and record more definitely their results, is the obscuration of one shadow by another which is superimposed. When a weak partial shadow is superimposed upon successively stronger shadows it becomes less and less definable until it is obliterated to the eye. At first it is reinforced, at the same time that its limits become less defined, but this reinforcement is less and less observable as the interfering shadow becomes denser. This principle explains why it is so difficult to see a hip-joint; the shadows of dense tissues are superimposed.

"Instructive experiments may be made with daylight or gas-light by folding a piece of paraffin paper so that it will present from one up to thirty-two or more layers. With some metallic object held between this paper and the light the gradations of partial shadows may be studied and the principle applied to X-ray examinations, for there is no essential difference in the behavior of the shadows. X-rays are singularly favorable to this method of shadow measurement, for they suffer no refraction, reflection, or diffraction.

"The skiameter devised for this purpose is simple in construction and principle. It is made by fastening strips of tin-foil upon strong cloth-covered pasteboard.

"This gives us an instrument made up of six notched and perforated bars of tin-foil, one metallic rod, and six equal interspaces.

"If now this *skiameter* is held in front of the fluorescing screen we see that we have a series of partial shadows of graduated densities. The tin-foil strip of two layers casts a heavier shadow than the strip of one layer. Five layers make a heavier shadow than the lesser layers. These are *partial* shadows because they do not entirely cut off the X-radiance. A knife-blade will cast a shadow upon the screen through any of the tin-foil bars, but not through the metal rod before the tin-foil, because the latter throws an *absolute* shadow. If a layer of tin-foil is interposed between the skiameter and the fluoroscope the smallest hole in the first bar becomes indistinguishable. If ten layers of the foil be interposed, the entire first bar becomes obliterated. If fifteen layers be interposed, the fifth bar is blotted out and only the metal rod can be discerned. The foil employed should be of such a thickness that the shadow of a single strip will be barely but plainly discernible just above the diaphragm during inspiration through a heavy man's chest, nine inches through. We have herein a method of measuring the density of a partial shadow by ascertaining how strong a known partial shadow it will obliterate. In the skiameter we have a series of partial shadows of known density.

"To measure any given pulmonary shadow, place the patient standing before an active Crookes tube. Hold the fluoroscope against the chest as usual, and hold the skiameter against the opposite side of the body. The Instruction Plates show the proper position of tube, skiameter, patient, fluoroscope, and examiner. (See Chapter XXXIV.)

"The shadows of the skiametric-bars are thus made to fall through the thorax upon the fluoroscent screen and are superimposed upon the

shadows of the chest. Note the weakest bar and the smallest hole discernible in a given field. Compare the two sides of the chest. Pass the skiameter over the thorax in every position. If it is kept slightly moving to and fro a closer reading may be made, because the eye will

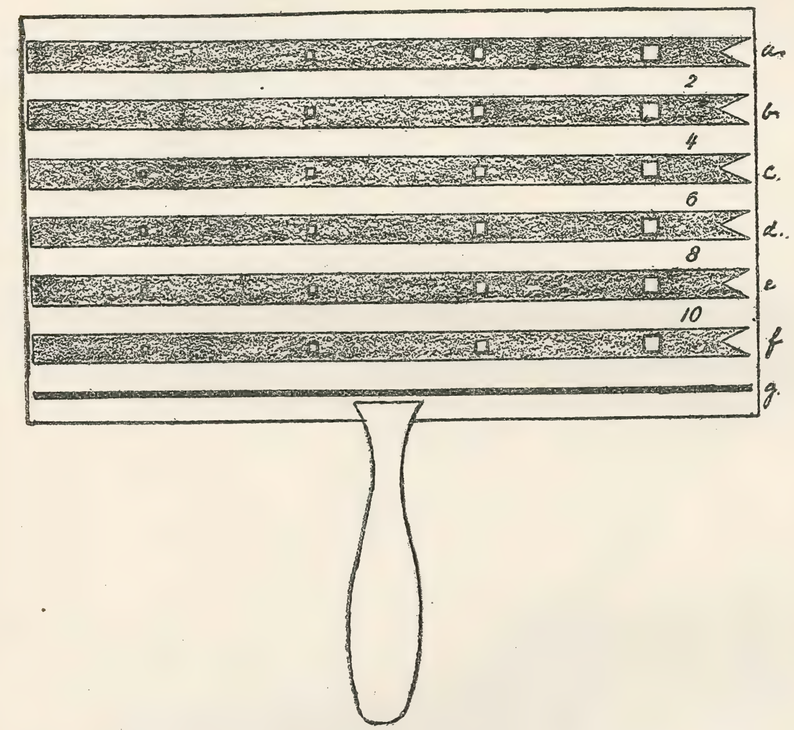


FIG. 13.—THE SKIAMETER OF CRANE.

Directions for making the Skiameter. Lay down six strips of tin-foil side by side, parallel with each other and separated by equal spaces. Make each strip and each space one cm. wide and ten inches long. Make the first strip of one layer of tin-foil, the second strip of two layers, the third strip of three layers, the fourth strip of four layers, the fifth strip of five layers, and the sixth strip of but *one* layer for contrast.

One cm. below the sixth strip and parallel to it fix a metal rod the size of a stout knitting-needle. In each strip cut a series of four small square holes equal distances apart. Make the holes run from 1 mm. to 4 mm. square and have the six series directly under each other in similar order in the strips of foil. Deeply notch the right end of each strip and fix wire figures (2, 4, 6, 8, 10,) in the successive interspaces near the notches. Add a handle and for protection paste a piece of thin muslin over the front surface. This completes the instrument and it is ready for use. See Chapter XXXIV. for photographs of uses.

perceive and appreciate a moving shadow better than a stationary one. The *holes* along the single strip are of great assistance. An infiltration which would escape the unaided eye may thus be observed and measured. The sixth strip of one layer lying between the metal rod and strip of five layers facilitates comparison. In practice it is found to be the most useful bar of the skiameter.

"*The tin-foil bar of one layer is the unit of measure.* If over any given thoracic area the examiner finds that the shadow of this bar is indistinguishable, while the shadow and holes of the next heavier bar can be seen, he has encountered a chest shadow of *one degree.* If the shadow, which will obscure a single strip of tin-foil, be taken as one degree, then the smallest hole in this strip may be taken as 0.2 of a degree, the next 0.4 of a degree, the next 0.6 of a degree, and the largest 0.' of a degree. The strip of two layers denotes *two* degrees, three layers denote *three degrees,* and so on. If a chest shadow is so dense that the shadow of the metal bar cannot be distinguished through it, then we have an absolute shadow.

"The *boundary* of shadows can be more clearly designated by the aid of the skiameter than without it. This is because superimposed shadows reinforce each other if their densities are not too greatly at variance. The shadows of the bars should run at right-angles to the margin of the shadow being examined. The eye can appreciate the difference in the skiametric shadows where they overlap the chest shadow more clearly than it can the difference between the chest shadows in disease and the normal lung-shadow. For this reason the skiameter is of real practical service in the general detection of pulmonary shadows even without any attempt at measurement. The two sides or parts of the same side may thus be rapidly compared.

"Whether or not the tube is producing exactly the same quantity and quality of X-rays in each examination with the skiameter is immaterial, because both skiametric and chest shadows are partial shadows and diminish or increase proportionately. The same explanation applies to differences in the distances of the patient from the tube. The difference in the thickness of different patients will make some little difference in the degree to which the shadows of the skiameter are magnified.

"The instrument may be used not only as a measure of density, but for linear mensuration. Each bar and interspace is one centimetre wide. One end of each bar is notched, and wire figures mark each interspace. For the latter purpose the skiameter is placed not on the distal surface of the body, but close against the fluoroscope so that the notched ends of the bar form *a centimetre scale* running across the field in front of the patient's body. *The apparent size of pulmonary consolidations, of cavities, of the heart, and the excursions of the diaphragm can thus be conveniently measured.* The difference in the position of the diaphragm in ordinary inspiration on the two sides may be measured by placing the skiameter so that the metal bar at the bottom is at right-angles to the spinal axis, and so that it marks the position of the lower diaphragm. Then the position of the other side may be read on the scale.

"The skiameter is an instrument designed for practical use in the fluoroscopic examination of office and hospital patients suffering from pulmonary diseases.

"In the absence of any special method of recording the results of these examinations the author suggests the use of Keen's clinical charts."

PLATE 29.—Faulty Methods of Examination. Study these and avoid the obvious errors. In the upper figure see the slanting relation of the axis of the rays to the part under the photographic film. If the thorax is radiographed in this manner distortion will make the result useless. See our teachings on divergence and distortion. In the lower figure see how far from correct is the axis of the rays with the screen and patient as shown. These two illustrations teach "how not to do it" with great clearness. All such work is mere trifling with the scientific principles of technic and is unworthy of anybody.

PLATE 30.—Instruction Plate teaching use of author's Frame to examine any part of the head in the axis of the rays. The dotted lines on the exposed screen mark the axis at their intersecting point. The front and back markers shadow these lines on the screen and all parts of the head can be brought into this field of non-distortion.

PLATE. 31.—This plate illustrates the "Ortho-diagraph" of Dr. Moritz, "an apparatus designed to permit the accurate mapping out of internal organs without taking a picture." It aims to limit the screen observation to a diagnostic field through which only perpendicular rays pass, cutting out the slanting rays of side fields beyond the axis-centre. This is done by bringing certain lead marks into register when a simultaneous moving of both tube and screen fixed in the same frame brings each part of the body in successive view till the entire part is examined as desired. The outline of the heart, for instance, is thus seen in a series of continuous observations which keep it at the normal size without the enlargement caused by divergence. (A glance at the author's Divergence Chart will make clear the fact that the central-axis rays do not enlarge a shadow.)

With the patient on a table and both tube and screen fixed in exact relations to each other in a frame which can be shifted over the entire field of examination without losing the axis of the central rays the object is accomplished. The engraving shows another view of the apparatus. The principle involved is about the same as in the examining frame independently originated by the author and described in other plates. (Rebman, Ltd.)

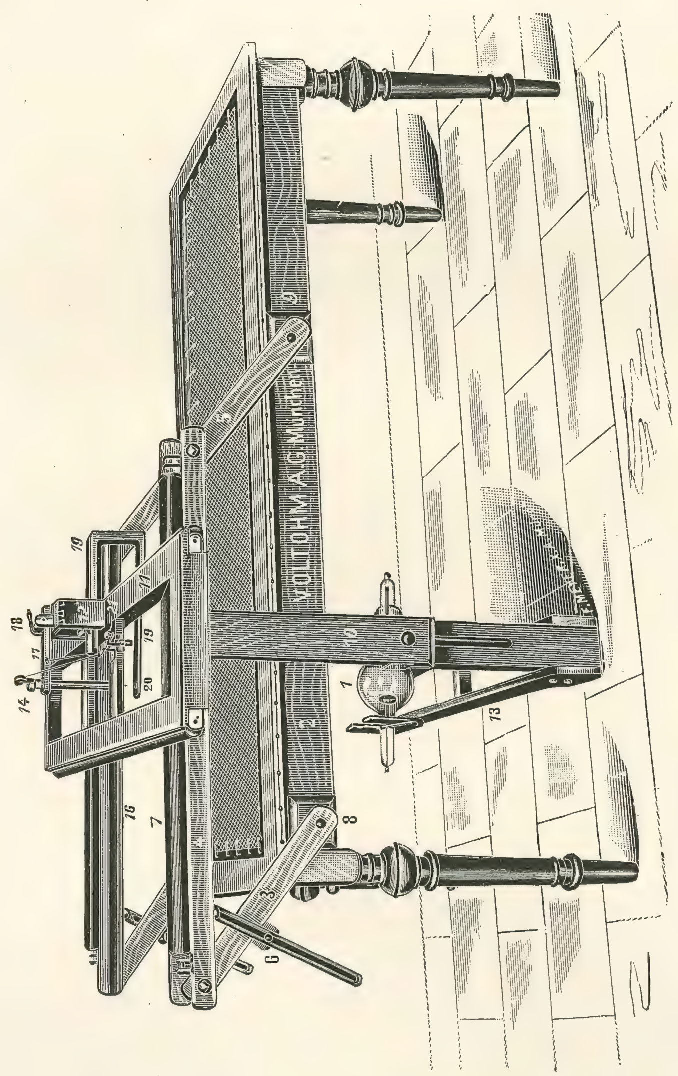


PLATE 32.—This figure shows the Ortho-diagraph in greater detail than in the preceding half-tone. Its adjustment on the operating-table, the position of the tube-carrier, and the fluorescent screen with movable markers are all made clear in this illustration.

How to Outline X-Ray Shadows on Tracing-Paper.—A tracing may often be valuable for record. Though most physicians have read of the method only with reference to the heart, yet many other records of great value can be made, as will now be taught. The regular fluoroscope cannot be used. An open screen mounted in its frame without the box is required. Then of small strips of wood make a frame which will just fit inside of the frame of the screen, and clamp fast the tracing-paper laid inside the screen. Ladies who do embroidery have a pair of rims to hold their canvas or linen on the stretch, and we apply the same idea to holding our tracing-paper. The screen must also be secured at a right-angle with the axis of the rays so as to leave both hands free, and the eyes must be protected from the light of the tube. Therefore:

Place the author's *examining frame* in position in front of the tube and suit it to the level of the part to be examined, as taught in section describing this device. (Chapter XXIII.) Lay the piece of transparent paper inside the fluorescing screen, and with the inner frame press it into close contact with the fluorescing surface and clamp it fast. Then clamp the screen on the examining frame as usual. Bring the part to be examined into the fixed field as taught, and start the tube into action. Shift the part for final adjustment of the shadows into the exact field outlined by the markers of the frame (which are previously placed as may be desired), and throw over the head a large black cloth so as to inclose the eyes, screen, and entire field of observation from outside light. The shadows will then plainly appear.

To avoid magnification keep the tube not less than twenty inches away for thin and medium parts, and thirty inches away for the trunk of the body. To secure the best degree of shadow regulate the tube to produce the correct degree of radiance.

Then with an ordinary lead-pencil trace the outlines on the paper. It is well to also trace in the lines of the markers to show the relations of the parts to the rays. When done stop the tube, remove the patient, unclamp the screen, take out the tracing-paper and write on it the notes of the examination. To record, preserve, and prepare for reference mount the tracing on white cardboard, which will make a white background for the tracing and bring the marks into plain relief.

The interference with the normal shadow-power of a screen by tracing-paper in front of it is not very great. It would cause some faint shadows to be lost, but with a well-darkened field of observation, obtained by the aid of a head-cloth, the operator can make records of surprising accuracy and value.

Author's Heart Outliner.—This device is designed especially to mark the margins of the heart on both skin and record-sheet without the difficulties and errors common to ordinary methods of tracing. In tracing an outline directly on the skin with a fluoroscope the screen must be lifted enough to let the crayon or pencil mark under it, and this causes some deviation of the line. To transfer the tracing later to a record blank is some trouble in addition. If an open screen is used and the tracing made on celluloid, glass, or paper (as many do it) there is some enlargement due to distance between the pencil and the body casting the shadow, and transference to the skin, if desired, is also some trouble. These difficulties are less to one who has a draughtsman's skill, but the novice finds them awkward. The author's device aims to eliminate the trouble. As most of the needs of tracing exact sizes and borders relate to the heart the following description will apply chiefly to this organ, but other sizes and shapes of the instrument can be made by any one. A set of large, medium, and small (three sizes) would cover all essential work.

At any tool shop have made a thin broad rim like the rim of a wheel, say, out of stiff sheet-brass three-sixteenths of an inch thick. Turn smooth and polish down. Make the rim nine inches across with its inside diameter eight inches. Take thirty-two narrow strips of thin spring steel (or any convenient metal) six inches long. Then channel one surface in radiating grooves to closely fit the metal strips so that each will stay firmly where directed by the operator.

Insert each strip in its groove and we have a wheel with flat radiating spokes, each of which can be moved from the rim to the centre and left stationary at any intermediate point. Every spoke will cast a shadow, and we are now ready to use the *outliner* to ascertain the exact size of a patient's heart *without magnification, distortion, or difficulty, and with a simplicity of technic not equalled by any other method.*

Strip the chest of the patient; level the focus of the tube with the author's examining frame (as taught), and at a suitable height for a sitting position; have the patient sit in the frame; clamp on the fluoroscope or open screen (whichever you prefer to use) and start the tube into action. Regulate the X-light dosage to give the clearest shadow of the heart, then slightly shift the patient so that one border of the heart will engage the marker of the frame. Slip the "Outliner" between the patient and the front of the frame and have the tissues hold it in place by close pressure. This border will then be exactly in the perpendicular axis of the rays coming through the body, and there can be no distortion or enlargement of any appreciable amount.

Keep the eyes in the fluoroscope to direct the strips, and with the convenient hand, right or left, according to the side of the heart engaged) successively push down strip after strip so that the tip of each stops just at the border of the heart shadow. When the margin engaged in the "marker" is outlined have the patient hold firmly the rim of the instrument while he shifts his body till you engage another border or section of border in the marker. Then push down other strips as before, and continue till all the visible free border of the organ is registered by the tips of the metal strips. Have the patient hold the rim steadily in position and slip out of the frame. Take any charcoal crayon, or dermal pencil, and run a line on the skin continuous with the margin indicated by the ends of the radiating spokes. To mark the record-sheet simply lay the Outliner on it and pencil the liner as indicated by the tips. The process is then complete.

As the outliner has been in close contact with the skin during the process of adjusting the strips, there has been no magnification added to that of the parts. As the fluoroscope is also in close contact with the tissues there is no such deviation as is caused by using it one or more inches from the tissues. As the borders marked in succession are each placed automatically in the axis of the rays by the examining frame there is no spread of the shadow such as is caused by diverging rays. The whole process being mechanically accurate, there is none of the uncertainty inseparable from all previously taught methods. It is more quickly done than any other method. The difficulties of transferring a tracing from celluloid to skin or from skin to paper are obviated. Any one can have the outliner made at home from the above directions.

To Compare Heart Size at Future Examinations.—For this purpose the Outliner is par excellence beyond all other crude attempts. Simply take out the original record blank, lay the outliner on the marked lines, shift the strips to conform, place the patient in the examining frame, and with the aid of the screen engage the heart in the space within the tips. Any alteration in size will be mechanically shown. The uncertainty of the troublesome measurements usually taught are obviated. The outliner is an advance in heart technics that revolutionizes X-ray examinations for size and position, for position is exactly shown and recorded at the same time the size is marked.

The same principles apply equally to measurements of tumors or other shadows which can be made out on the screen. For small work a rim with an opening four inches in diameter could be made, while larger work than we have here considered can be similarly lined out by having a rim big enough to take in the part.

graphic plate put in place of the screen is less affected by the rays from the hard tube. The latter go through the film, and will go through ninety-six films, and impress the last one while the first is scarcely over-exposed. For this special reason hard tubes require longer exposures, while very soft tubes need longer exposures on account of their feebler intensity."

This is satisfactory and correct under the conditions of Roentgen's tests, but as practical radiography can modify the conditions of scientific investigation the latter half of the above extract calls for a little interpretation lest it confuse the reader.

The discrimination made between rays from "hard" versus "soft" tubes must appear contradictory to the novice. The terms, hard and soft, are obscure, and, though they have come into too common use, they mean nothing definite unless qualified by considerable explanation and a statement of the dosage of the exciting current. In the second place, the slight difference in activity on plate versus screen, noted by Roentgen in his open test, is negligible in actual work directed by methods of approved practice. Lastly, the puzzling assertion that the most penetrating rays require a longer exposure, when the common experience is the contrary, evidently needs the interpretation that they require relatively more time to affect the film than would be computed by comparison with feebler rays. But the absolute exposure time is shorter and not longer, as the beginner might infer.

But Professor Roentgen dwells on other points of his investigations which throw important light on the use of the brass background advised by the author in another section. He says:

"In a tube in action X-rays come not only from the focus spot on the anode, but, more feebly, from the whole plate and a part of the wall of the tube. Even the air, when struck by the rays, sends out X-rays in all directions, and these rays are photographically active."

Herein lies the value of an opaque diaphragm and window, as elsewhere described, to shut off lateral extra-rays and assist to secure the highest refinement of radiographic definition. And, having cut off most of these fogging side rays, and noting that the direct rays of the highest penetrating efficiency go through ordinary plates without stopping quite long enough to exert the most rapid actinic action on the film, we have only to back the film with an artificial "stopper" and we accomplish two purposes at once; we check the fleeting rays so that possibly an enhanced "absorption" is secured, and by the impact of rays of high intensity, striking an impervious body nearly

or quite at right-angles, we have a new creation of rays and a sharp reinforcing fluorescence on the film. Thus the primary fact that rays pass too easily through flexible films, such as Roentgen reports that he used in his tests, works out for greatly improved, instead of slower, results when we not only back the film with somewhat retarding glass, and to this add completely opaque metal. So far has the general reader ignored these practical facts that they will doubtless seem new to many.

But besides the general question of the function of the radiograph as compared with the fluoroscopic ocular view, we consider in each case the function of the individual radiograph—the purpose for which the negative was taken. Refinements of technic now divide radiographs into two important and quite distinct classes, the function of which is materially different. Few beginners are aware of this.

The different functions of radiographs primarily grow out of the individual requirements of diagnosis, one being simply to show presence or absence of a foreign body; another to exactly determine its location or size; another to show anatomical relationships; another to define details of structure; another to contrast densities; another to discover the fact of an alteration from normal; another to illustrate the normal; still another to compare the normal with the pathological; and so on, as will appear throughout subsequent chapters of this book, but in this place we refer to two broad subdivisions of function as relating to:

1. *Momentary* exposures of parts having physiological movements.
2. Time-exposures of parts at rest.

Distinctions novel to the beginner are set forth with instructive fulness in the writings of Von Ziemssen and Professor Rieder, of Munich, whose authoritative X-ray work needs to be more widely known in this country. The great function of the almost instantaneous radiograph is to picture the thoracic organs, especially the heart, in a state as near as possible to rest, and imaged on the plate during *a single phase of respiration.* The exact method will be duly described later. The possibilities are of exceeding interest to internal medicine, and every reader who has noticed abstract references to such work will be instructed in this book exactly how to do it himself.

Dosage of X-Radiance for Radiography.—At all times it is well to have a liberal stock of tubes so that they can be used and rested in rotation, and thus remain long in working order instead of rapidly reaching too high a resistance. The proper way to obtain selected degrees of X-radiance for given work is to regulate the factors on which radiance depends. A single tube can thus be adjusted to any one of a dozen degrees of action, and modern "regulating" devices have put the process on the simplest basis.

Granted, then, that we may regulate any proper tube to any desired intensity of radiance, let us see what are the requirements of practical work. It is not the therapeutic rule that the greater the dose of medicine the better the effect, and it is not the X-ray rule that the greater the intensity the better the radiograph. The "dose" must be adapted to produce the desired effect. Some effects result from a small dose of X-rays; some require a larger dose; some tax the utmost capacity of the apparatus to secure them. In each case the best result is obtained by a suitable penetration and richness of rays without much variation above or below what is needed.

The beginner will get the idea correctly from a simple test. Into a wooden box place a large leather bag containing a little assortment of bone, ivory, pearl, vulcanite, and metallic buttons. Start the tube into the feeblest action, and at three feet from the anode begin a fluoroscopic examination of the box and contents. Test the contrasts of shadow at each distance up to a single inch from the tube wall, and with a gradual increase of the current up to the maximum X-radiance. Note that a dosage which yields the best definition of the wood of the box and the leather of the bag has no penetrating effect at all on the dense metallic objects. When the dosage brings out the best detail of the bone buttons the wood is about lost. To pass light through the most dense contents the higher dosage obliterates all the fainter shadows that were best studied far below the maximum. A few minutes devoted to this study teaches that in radiography:

1. A small X-ray dosage will produce the least contrast between soft parts and contained bones or a bullet.

2. A high dosage will produce the most contrast between flesh and bones or bullets.

3. A short exposure with a high dosage and a long exposure with a low dosage do not produce equivalent results.

4. Rays of great penetration produce great contrasts between bodies of greatly different density, but not between bodies of slightly differing density.

5. Rays of medium penetration combined with great quantity produce the best contrast and definition between bodies of moderate difference in density.

6. Rays of great quantity produce the greatest amount of definition at all degrees of penetration.

7. Rays of great quantity act more intensely on the sensitive film than rays of the greatest penetration with less quantity.

8. A dosage that is high at a short distance is lower at a longer distance, and will be very low at a still farther distance from the plate.

9. Nothing in practical radiography calls for a very small dosage of X-rays.

10. *All* work is aided by the factor of *quantity*, and the factor which requires regulation in dosage is the *degree of penetration.*

As part of the dosage is always arbitrarily out of the operator's control and linked with the construction of the apparatus (especially the factor of quantity) do not try to learn from printed directions how to dose the tube, but *make tests of effects* by radiographing muscle organs within soft parts, thin bones within thin and thick parts, and thick bones in thick parts, and record as nearly as possible the dosage used. The author's gauge enables this to be exactly done.

On a plate lay a piece of one-fourth of an inch wood, six overlapping pieces of cardboard, and several layers of cloth. Then try to secure the best contrast which will retain all the shadows. When the short exposure, the proper distance, and the medium dosage of rays has been worked out for this result, the experience will cover a great range of radiography for diagnosis. It will be especially helpful in aiding to detect calculi of various kinds, and this is work that seems difficult to most physicians who have not worked out the "dosage."

CHAPTER XIII

RADIOGRAPHIC EXPOSING TECHNICS

RUDIMENTARY STUDIES. POSITION OF TUBE IN HOLDER. DISTANCE OF TUBE FROM FILM. RELATION OF TUBE TO PATIENT. POSITION OF PATIENT FOR RADIOGRAPH. STATE OF TUBE. PRELIMINARY OBSERVATIONS. IMMOBILIZATION. PRACTICE EXPOSURES FOR BEGINNERS. EXPOSURE TIME. PROPER RECORDS.

MANY of the rudimentary steps of X-ray work are as strange and difficult to the novice as radiographing a gall-stone is to an expert. Most writers pass them over as too small to mention, but a new student needs to know them and we shall consider the basic steps in this chapter.

Position of Tube in Holder.—Secure the tube in the holder so that the diagonal electrode within the tube faces the object which is to be examined. Also set up the tube so that the diagonal electrode (the anode) is nearest the positive side of the battery, and the round concave electrode (the cathode) is nearest the negative side of the battery. It is obvious that the rays can be directed toward the patient or the examiner with the tube in a wide variety of positions, some of which will be far less convenient for the connecting wires than others. Therefore, while the first need is to adjust the tube so that the platinum reflector fronts toward the patient, it is wise to adapt this adjustment to the position best suited to carrying the connecting wires between the terminals of the tube and the battery. This position approaches the horizontal in the majority of cases. Having first made the general connection in the manner adapted to regular work, the final modification of adjustment is made to suit a special examination. These adjustments consist of slight turnings of the tube one way or another to conform to the best examination of the part after the proper general connections of the tube have been made.

Distance of Tube from Film and from Nearest Surface of Patient's Tissues.—Theoretically, the greater the distance between the tube and the plate the more perfect the picture will be. Practically, the working power of X-radiance diminishes so rapidly with increasing dis-

tance that very little work is attempted beyond three feet. A very thick part of the body can be radiographed at three feet with as little enlargement of the shadows as would be caused at one foot with a thin part. The needs of the case do not require the operator to put the tube at the greatest distance his apparatus will work. The chief reason for making exposures with the tube closer to the plate is the more rapid chemical action and the shorter time required.

A compromise, then, in the matter of distance, *aims at approximating normal shadows with reasonably short exposures.* Small work may be wisely done at distances of from fifteen down to ten inches between the anode and the plate, in order to secure rapidity of action. Medium work is satisfactorily done with fairly short exposures at from sixteen to twenty-four inches between the tube and plate, and, as it is well for the operator to accustom himself to a standard measured distance for all work falling within its class, it would be well to adopt *twenty inches* as the *standard* distance for medium densities and thickness.

Through the thickest parts of the body the requirements of the radiograph may differ in different cases. It is wise to get the tube not only far enough away from the plate to reduce the divergence to *a low angle*, but also to get far enough away from the nearest tissues of the patient to avoid every conceivable liability of damage, even though the risk is of microscopic size. While it is considered that twelve inches between the tube-wall and the tissues is sufficient for safety, yet some operators make thirty inches their rule with the trunk of the body. Very high-efficiency apparatus is required to make a rapid picture at such a distance. The beginner will do well to avoid both extremes.

With small and medium work references to distance mean the distance between the *anode* and the *film*. In exposing the trunk of the body, we take into account the distance between the wall of the tube and the tissues, and if this is never less than twelve inches the operator conforms to good practice with reasonable limits of exposure.

It may be said here in passing that modern radiography with efficient apparatus never demands the exposure of a patient for a period more than a third or a fourth of the time required to render the patient liable to dermatitis. In small and medium work the exposure is usually less than a twentieth of the time required to cause irritation. If the beginner keeps his tube not less than twelve inches from the tissues in any exposure that lasts more than five minutes he will have a large margin of safety.

Test for Relative Distances in Radiography.—It is the rule in radiography, as in all definition of shadows cast by any form of light, that the object must be near the plate or screen, and the point of light must be neither too far nor too near, but at a distance which is related to the width and thickness of the object shadowed and such that the rays will pass its edges with a minimum of diverging angle. The author's Divergence Chart teaches all variations of this rule in visible diagram, but to test the matter in a radiograph take a pine block four inches square, run a diagonal line from one corner to another, and drive in a row of small wire nails one-half inch apart on the marked line.

Lay the block on a plate in its paper envelopes and have the nails horizontal to the film, but rising like steps from contact with the plate to four inches distant. Then expose with the tube at ten inches, and again at twenty inches, and again at thirty inches, and develop all the plates and compare the joint actions on the size and clearness of the nails, noting:

1. The space between each nail and the film, and
2. The space between the nails and the point of light in the successive pictures.

At the distances which permit the object to be spanned by rays which make the nearest possible approach to parallel, the shadow of a given nail (or any object radiographed) will be the nearest life size and have the sharpest outlines.

Relation of Tube to Patient.—As the tube contains the anode it has become the general custom to refer to the position of the *tube*, but it is very unscientific to do so and allows too much latitude for accuracy. The important thing is the focus point. The relation which this should bear to the patient must be considered from two stand-points: distance and perpendicularity. An object of much thickness on a photographic plate will be magnified too much if the focus is too near. The shadow will be carried too obliquely if the focus directs slanting rays through it. Therefore, to obtain radiographs of diagnostic value the shadows must be as nearly life-size as possible and as free from distortion as possible. Studies of distortion in another Section make the reader familiar with its causes.

The rule of correct practice is simple. *Adjust the focus far enough away from the part to magnify it but little*, and *straight enough over the part so that the rays striking the centre of the plate will be perpendicular*. The author's Divergence Chart and Position Finder are exact guides to securing the correct relation of the focus with the patient. They are described in their special sections.

If the shadow of any part within a part is sharp and not magnified,

PLATE 33.—Radiograph of Shoulder. Note manner of making close contact with the film by side position of patient. Operator holding watch to cut out current.

PLATE 34.—A Correct Exposure of the Ankle. The tube is fixed centrally with the focus at right angles to the part. The plate-holder and foot-rest are adjustable to distance in the path of the rays, but cannot move out of axis. Slide it to twenty inches from the anode, place the foot in position, insert the film or plate, press the part against it, and make the exposure.

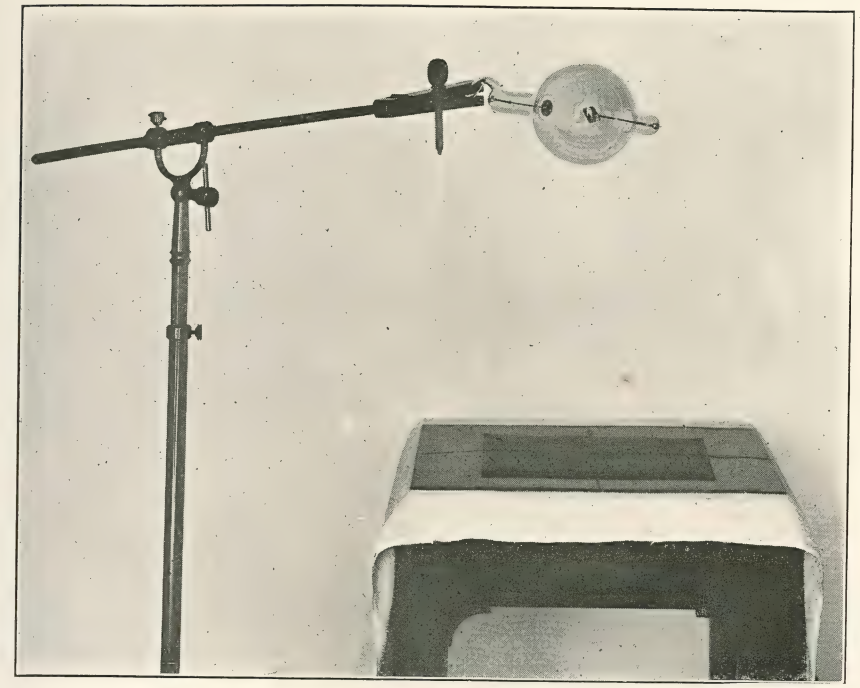


PLATE 35.—Cross-wires for marking quadrants on negative. It is often useful to so mark the negative that it will show the central point of exposure with the field divided into four right-angled parts. This Instruction Plate shows a plate in light-proof envelopes on a base which has two cross wires drawn tightly over at and intersecting in the middle. Focus the tube vertically over the point of intersection and freshly wet the cotton wrapping of the wires with any ink that will mark the skin. Then place the part on the plate and make the exposure. The marks of the wires will be imaged on the negative by the rays and printed on the skin by the ink. Thus the radiograph and part can be compared after the plate is developed and any desired measurements may be made. This device is especially employed in making stereoscopic radiographs. It is well to lay a metallic letter R on the upper corner of the right-hand quadrant to identify it for all examinations.

PLATE 36.—This plate shows the markings on the negative of the cross wires illustrated in the last figure which divide the picture into equal quadrants and assist in defining the examination of the negative and print. Some operators use this form of landmark for all radiographs.

it is proof that the object casting it was near the film, and per contra, if any shadow is enlarged and hazy on its borders, the tube distance in both cases being correct, it is proof that the object is at some interval from near contact with the film. These laws of definition are both well illustrated in the frontispiece, the two circles being made of the same steel wire. The contrast is more extreme than in any part of the body, because the hazy circle was a greater distance above the film and nearer the tube than tissues are.

Position of Patient for Radiograph.—Cases fall into two classes: those who can move freely and assume any desired position, and those who cannot. Hospital cases in helpless conditions or immobilized must be exposed as they lie on the bed or stretcher, and the plate and tube placed according to the necessity. Some advise that the plate should generally be above the part and the tube underneath, but this is often more trouble and no better than some other pose. If the part is reversed in the picture because of the position of the negative during exposure, simply use a mirror in inspecting it, and the normal relation will appear.

We have all seen lengthy directions, even filling several pages, stating separately how each and every part of the body should be postured for exposure, and how the tube should be placed opposite a certain anatomical location, etc. To remember them would be a task if it were necessary, but happily it is not required for correct work. We shall here teach one universal rule that applies to every part of the body, and sweeps away all the confusion of past methods.

1. Select a plate adapted to the size and shape of the part.

2. With the fluoroscope, or by other means of examination, locate the field for examination and the best direction for the rays to traverse it.

3. Mark the centre of this field on the skin of the patient.

4. Centre the plate and tube by the author's Position Finder, the one method serving for all cases and parts; or, when more convenient, use the author's Examining Frame to place the tube. The principles are the same, and both secure vertical rays within the field exposed.

5. Place the plate in the frame, or on the base of the Position Finder (whichever is used), and simply insert the patient in the fixed path of the rays so that the marked spot on the skin is on the marked centre of the cover of the plate. The accuracy of the radiograph then becomes automatic for any part so placed. This is simpler than complex directions oft repeated in print by writers who make no effort to standardize their technics. See chapters on author's "Posi-

tion Finder" and "Examining Frame" for complete description of each. For distances refer to remarks on author's Divergence Chart. These standard teachings are here put in print for the first time.

In examining any thick part of the body, as the trunk, either with a fluoroscope or by making a negative, place the front, side, or back of the part in contact with the screen or plate according as the object of examination is nearest the front, side, or back. Follow the rule that the nearer the part to the plate or screen the better will be the shadow, and if a tumor, bullet, or organ is nearest the front then examine from the front. The principle is of general application. Remember it for all uses.

State of Tube.—Before making an exposure for a radiograph, always make a last test of the tube before the plate is brought from the dark-room. Not only ascertain by this test that the selected tube will instantly light up, but determine the regulation of the current which will produce the needed efficiency of radiance. Fine work requires that *the activity, penetration, and quality of the rays should be approximately suited to the case in hand.* The requirements for a picture of normal bones (especially thin bones) may differ much from the requirements for soft parts and for thick bones. The acquired judgment of the operator will, therefore, regulate his tube according to the part to be radiographed, and the *purpose* for which the picture is taken. The advance test is also important to save ruining plates. If the tube proves refractory another can be substituted before the picture is spoiled.

Preliminary Observations.—Accompanying the test of the tube should often go hand in hand a fluoroscopic examination of the part of the body which is about to be radiographed. It will save many plates to know in advance both where to put the plate and how to place the part. Operators who have been seeking to locate a bullet and have ignored the preliminary fluoroscope have time and again exposed a plate and found no bullet. On making a second exposure with a plate in a second situation the bullet has perhaps appeared on one end of the plate; but the first picture could have shown it without delay and with a minimum of obliquity if it had first been traced with the fluoroscope and the plate put approximately under it in the line of the anode. Fractures also illustrate the same point. View a part from several directions and determine in advance the best view point for the radiograph and the proper situation for the plate. Then proceed with the exposure as taught.

While the above point is briefly stated yet its importance will appear to the careful operator throughout nearly the entire scope of

his work. Find out in advance where the plate should go and from what direction the rays should pass through the tissues to secure the best result. It will save many laments.

Immobilization.—With less careful operators clear definition and sharp outlines are often blurred by slight movements of the patient during the exposure, or vibration of the tube in a tube-holder that lacks rigidity. All are familiar with the necessity of having the camera and the patient absolutely still during the making of a portrait, and the same rule applies to the radiograph. Different people vary to an extraordinary extent in their idea of keeping still, and some operators use a tube-holder so unsteady that it will be affected by walking across the floor. A rapidly run Static machine will also often conduct vibrations from the floor to the tube unless precautions are taken.

First make the patient comfortable and secure in the necessary position. Next instruct him to close his eyes just before the tube is started into action. Impress upon his mind that he must keep absolutely still and pay no attention to what is said or done around him, or he will spoil the picture. Ask him no questions and allow no one to touch or speak to him during the exposure when the posture is volitional. When parts are tightly strapped to a frame or table this precaution is not so necessary.

Removal of Clothing.—The entire removal of clothing from an exposed part is often advisable for some other reason than the effect of clothes on the penetration of the rays, which may be nil. As a protection against cold contact with a plate or chill in a cold room the retention of ordinary underwear is often permitted, but every layer of thickness in addition to the wrappers of the plate increases the space between the film and the tissues and lends some magnification to the picture. This is less when the tube is at a greater distance. In no case should the patient have any buttons, steels, pins, or anything that will cast a foreign shadow in the field. Even a fold of a thick garment may do this.

In surgical cases cotton bandages and wood splints offer little resistance to the rays and examinations are made through them, but if they prevent proper contact or relation of the part with the film allowance for the effect on the shadows must be made. Plaster and iodoform will cast shadows depending on their density, and if allowed for they need not be a source of error, though fine detail will be lost through them sometimes. Rubber tubes and even rubber or paste plasters may cast a slight shadow, which must be discriminated from disease. In fine and difficult examinations for primary diagnosis it is a good rule to clear the field from possible interference, but in merely watching progress all dressings can be allowed for.

Practice Exposures for Beginners.—Two persons who will measure the same diameter in the cross-sections through which a radiograph is taken will not require exactly the same exposure, with the same intensity of radiance, for the density of bone and soft parts differs with advancing age, and with the conditions of disease or health. The photographer taking landscapes or portraits, indoors or out, will observe the quality of light and vary his exposure accordingly. Exactly the same judgment must be used in X-ray exposures. To learn to readily approximate what allowance must be made, make tests with two subjects presenting some contrast in condition and age. Take four 10 × 12 plates. Fix the tube with the anode twenty inches above the centre of the plate. On one plate then expose an elbow from each subject, placed side by side in similar positions on equal sides of the centre. On a second plate expose two ankle-joints. On a third plate expose two knees. On the fourth plate expose the foot of an adult over forty years of age, and the foot of a child eight or ten years old.

Make each exposure with the tube working at the same efficiency, and give each plate the time you think best. Keep a record of it. Neither specific time nor distortion is important in these trial tests.

Develop the plates and compare the results. From the study of two or three series of such tests the beginner will derive sufficient judgment to make allowance for age and density in different subjects.

Exposure-Time.—All that can be advised about exposure-time by one operator using one apparatus can be disputed by another expert using another apparatus; and the critic fortified by theory and intrenched in confident ignorance can lay down still different rules for the beginner. With the same apparatus the expert can produce two negatives of good appearance, one with twenty seconds exposure and the other with twenty minutes. But just as we have advanced from the minutes of Daguerre and of ambrotypes to the quick photography of to-day so we will learn to regard X-ray exposures of minutes as the crude necessity of pioneer work. At present few men seem to object to two minutes as an ordinary exposure, but there are advantages in two seconds which will make two minutes obsolete as soon as plate-makers can mix an emulsion sufficiently rapid to X-rays. While many are not yet awake to the need of reducing these exposures to the plane of modern portrait photography, yet others appreciate the gain and are striving to bring it about through films of new composition unaffected by daylight.

PLATE 37.—Inspection of lungs posteriorly. Sit the patient on a chair higher than the one to be occupied by yourself. Level the tube as shown in this instruction plate. Have the patient raise both arms to remove the scapulæ from shading the pulmonary tissues, make close contact with the screen (or fluoroscope) in the axis of the rays at the standard distance from the tube, as here shown. The next step is to sit down comfortably in a chair that will bring the eyes easily on a level with the field to be examined, throw a black cloth over the operator's head and shoulders of the patient to enclose the open screen in darkness, and proceed with the examination as taught in the text. The operator has a choice of using a regular fluoroscope, or the screen taken from the box as here illustrated, or a larger mounted screen fixed on a standard. The latter is shown in plate illustrating the Skiameter.

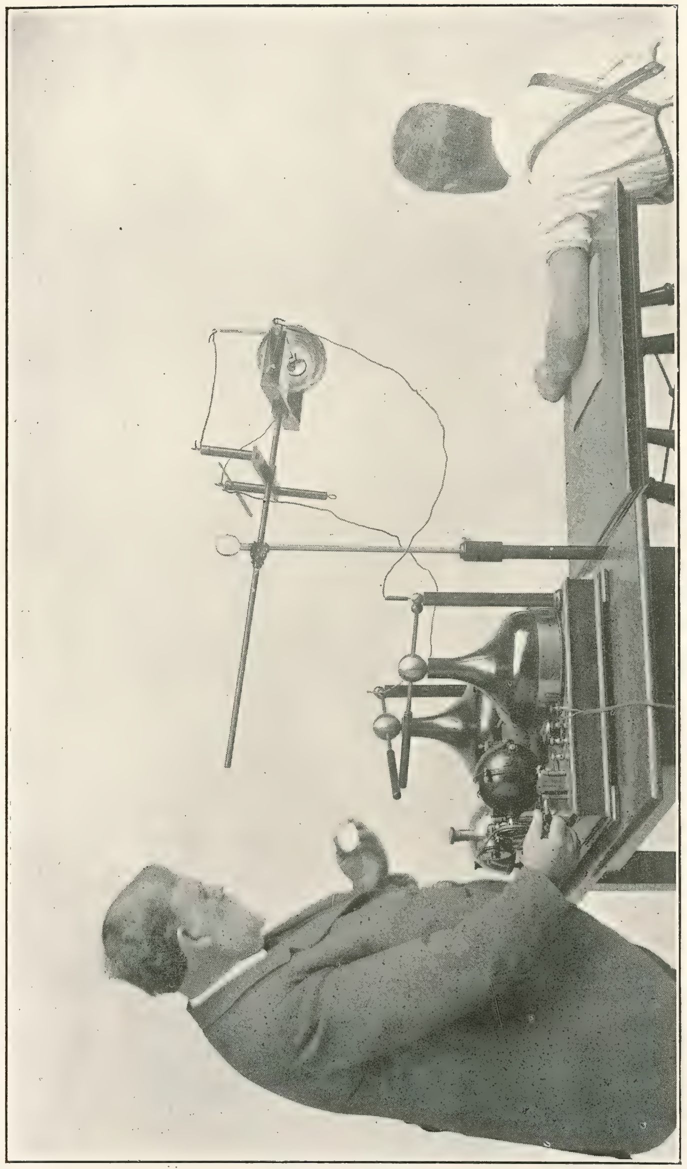


PLATE 38.—Showing ordinary manner of exposing elbow for radiograph. Compare it with technic of frontispiece and observe the greater accuracy of the latter. This plate also shows on the standard a simple shunt resistance regulator for adjusting the dosage of the tube. The operator is seen holding watch to time a five-second exposure with this coil.

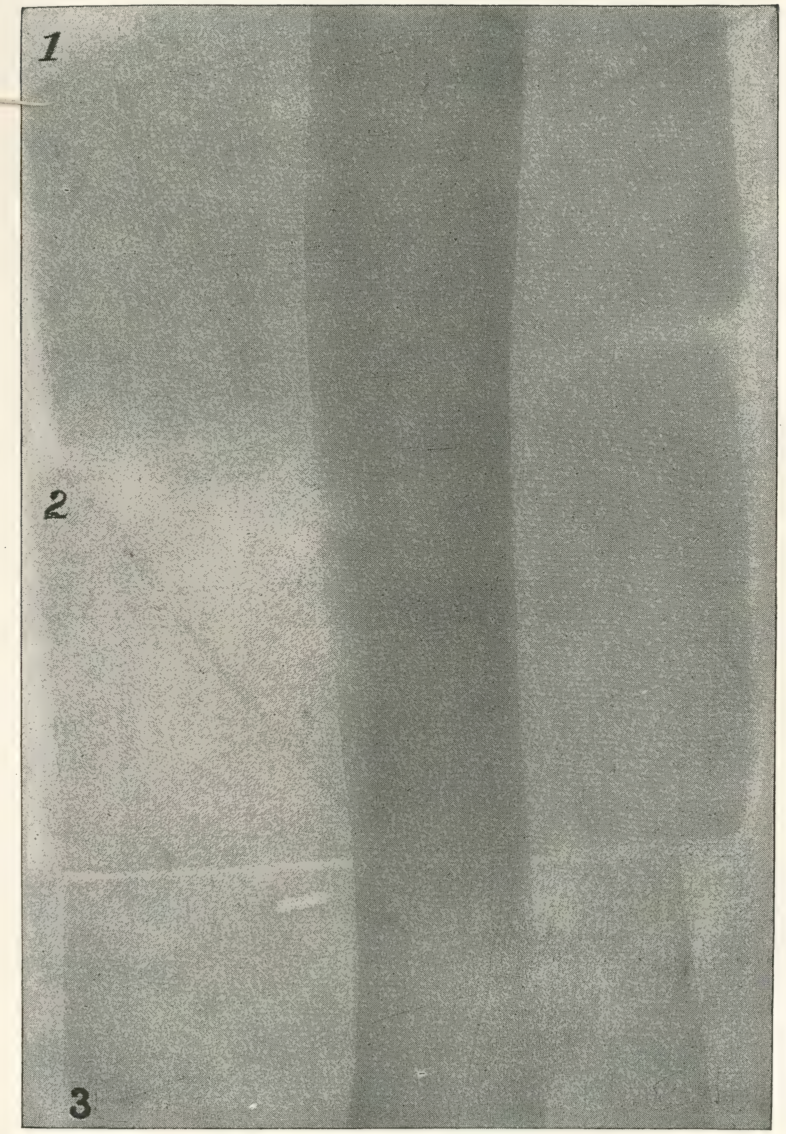


PLATE 39.—A Study in Penetration through different layers of plastic splints of different densities. Every X-ray operator should make test negatives for the instruction of experience. (Rebman, Ltd.)

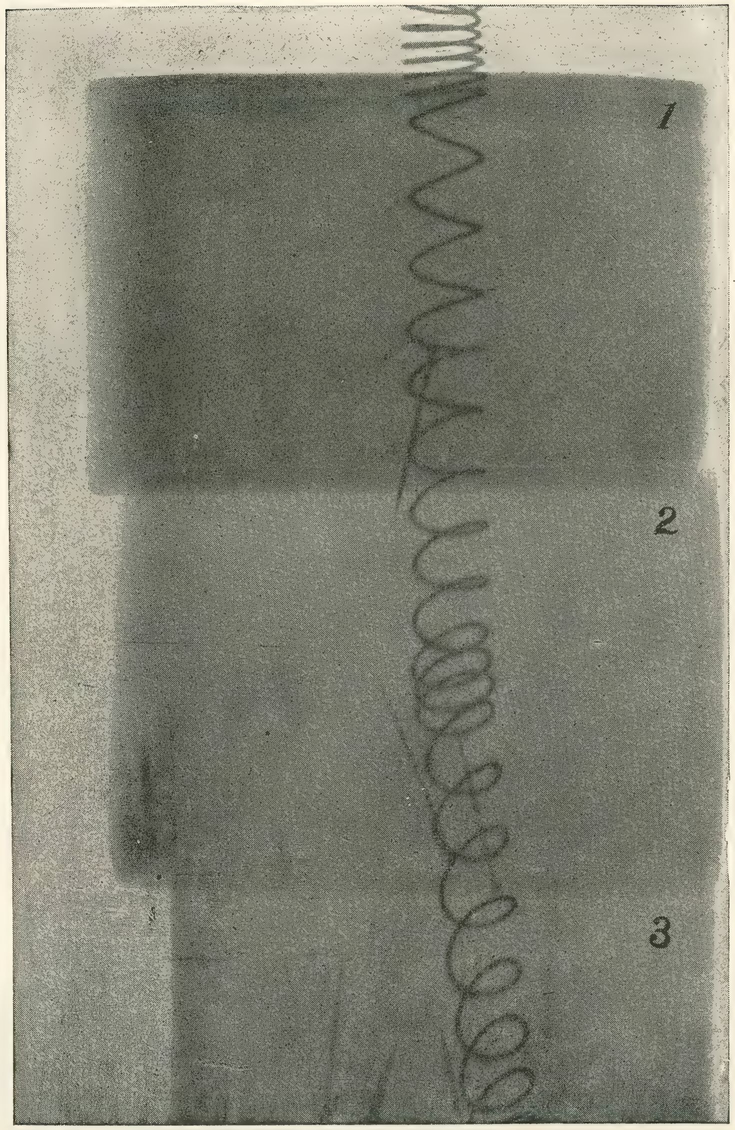


PLATE 40.—The beginner should make a series of negatives showing effects of different bandages, wires, pins, etc., entering into surgical radiographs. so as to become familiar with penetration and shadows. (Rebman, Ltd.)]

Recently a writer of international reputation expressed the general view of experts as follows:

"It is very often overlooked that, apart from the benefits accruing to the patient and the operator, a short exposure also greatly minimizes some of the technical difficulties which attend exposure, particularly of the deeper tissues. All are aware that in addition to the direct emission of X-rays from the anode there is a plentiful generation of secondary or diffused X-rays from all particles in the body through which the rays pass, and also in the surrounding air. This radiation is in itself feeble, but may and does affect the photographic plate if it lasts a considerable time. Reducing this time is, therefore, equivalent to reducing the disturbing effect of these rays upon the plate, an effect with which you are all familiar; namely, the foggy appearance of long-exposed plates. Moreover, I believe there are certain electro-static phenomena which also produce an effect upon the plate when exposing the latter for a prolonged period to a highly charged tube. Thus, generally speaking, a short exposure is likely to give more contrast in the negative, quite apart from considerations of economy, which should direct our efforts toward reducing the time of exposure by every means."

The factors which control the time required to produce a picture are (1) the activity of the radiance; (2) the rapidity of the emulsion; (3) the means employed to increase actinic action; (4) the thickness and density of the part, and (5) the personal equation behind the technique. These factors are directly influenced by the efficiency of the electrical instalment and the tube. While equal work cannot be done with widely different capacities of apparatus, yet the mere factor of *time* can be shortened with weak rays by getting them close to the film. This, however, is not good radiography.

A table of average minutes for each part of the body may be printed in a dozen different ways without benefit to the novice who is alone in his office, with but *his own apparatus to work with.* By extraordinary methods of detail experts can compile a similar timetable, in which minutes are reduced to seconds; and many specimens of "instantaneous" pictures have been made. Ordinary practical, surgical, *diagnostic* radiography is quite another thing. The object is not to make the shortest possible exposure, but to make the exposure which will produce *the character and degree of image required for diagnosis.*

What we shall aim to do here is to substitute for the prevalent rule of printing a list of exposure-times a practical method of instructing each operator how to *find out the capacity of his own apparatus* with scientific precision and without ruining plates by guesswork exposures.

Make the following series of tests on each part of the body of a normal adult of medium proportions. By each part of the body we here mean hand, elbow, shoulder, thorax, foot, knee, hip, and skull. First test the standard distance of twenty inches between the anode and the plate. Use for these tests a small plate, as the purpose is simply to ascertain the relation between the defining power of definitely ascertained degrees of X-radiance and your watch. The size of the picture is not important, and small plates cost very little.

Conveniently out of line with the plate, but in the path of the rays, adjust the author's X-ray penetration gauge at the distance of twenty inches from the anode. Use the set of thin shutters, which permit the finest differentiation of light.

Start the tube into action, and when it attains about the degree of efficiency which represents what you can usually rely upon with your apparatus, measure and record the penetration. Then, make one exposure of the selected part with an accurate record of the time. Let the first exposure be a little less than what you think would be necessary. Remove the plate and immediately expose a second plate with the same degree of radiance, and for one-third longer time. Make a third exposure under the same conditions, doubling the time of the first exposure. If possible to increase the brightness of the tube to a marked extent do so, and, having measured the radiance, make a final exposure of the same duration as the one preceding it.

With these records, and each plate marked for identification, develop them and compare the results. One plate will be under-exposed, another may be exposed unnecessarily long. Having determined which plate is the most satisfactory radiograph, the record of its time and other details of technique afford a starting-point for the next test. Take a somewhat thicker part, and estimate the allowance of time required for the additional density. Base the estimate upon the results of your *best* picture in the first test. Adjust the tube to exactly the same degree of efficiency and expose a new series of three or four plates. Having developed them, a comparison of the results will be *far more instructive as to the capacity of your own apparatus* than will a large amount of reading about results made in Germany.

Following this series of tests the operator can in the course of time compile his own records, which will be of the greatest value to him in his individual work. Make them gradually cover records of the photographic activity of an ascertained degree of penetration at a known distance from the tube through the different densities of the body, with relation to subjects of different ages and of different bony and muscular development. On the results of these tests future work

may be based with scientific precision with respect to your own apparatus, whether it is any type or size of coil, or any type and size of Static machine, whether your tubes are high or low, new or old, plain or complicated. *Exposures will thus be taken out of the uncertain realm of guess-work, and the watch, the gauge, and the record will save many plates* of much greater cost and importance in actual future work after these tests have laid the foundation of *accuracy.*

Note that neither the brightness of the apple-green phosphorescence of the tube-wall during an exposure, nor the appearances observed through a fluoroscope by the unaided eye, are a scientific basis for precision in timing exposures with different tubes, or the same tubes on different days. But the author's standard *gauge* permits a measure of the richness and penetration of the X-ray discharge which is mathematically correct. Full directions are given in the Section describing this instrument.

Timing Exposures.—For this purpose a sweep-second, fly-back timer will be found convenient. They are made to time from 0 to 30 minutes. The sweep-second hand marks seconds in fifths. A small hand marks the minutes. When ready for the exposure pressure upon the crown-push starts the watch going. At the end of the exposure a similar pressure stops the hands, and they remain stopped. The record can be noted at the operator's convenience, and when ready for another exposure a pressure on the crown sends the hands back to zero and a new start is made as before. When much work is done, especially in a darkened room, the ordinary watch-dial is unsuitable, and a timer of this kind is certainly a useful if not an indispensable adjunct.

Making Records of Exposures.—In reporting coil-work the record of the current exciting the primary should be stated always; and with the increasing variety of interrupters it is as necessary to state the kind of interrupter used, and, if possible, the approximate rate of frequency, as it is to mention the size of the secondary coil.

But when the author's practical X-ray gauge becomes the universal standard measure of X-radiance at any distance from the tube the two essential factors of record will simply be (1) whether the rays were X_1, or X_3, or X_5, or X_{10} in power, and (2) whether this degree of power was active at ten, fifteen, twenty, or more inches from the focus.

The record of the exponent power of X, and the distance of the anode from the surface will also greatly advance the standard of dosage in X-ray therapy. The habit of making complete records should be cultivated, and the operator should obtain the few instruments needed for accurate records of genuine scientific value.

CHAPTER XIV

STUDIES IN PHOTOGRAPHIC TECHNICS

Treatment of X-Ray Plates after Exposure. Developing Processes. Elementary Practice for Beginners.

No part of radiography seems so formidable to the novice as the part which takes him into the unfamiliar domain of the photographer's dark-room and asks him to develop his own plates. The already expert amateur has no obstacle of this kind, and after a week of practice the novice will lose timidity and find interest and recompense in this important and not too difficult branch of technics. Occasionally the demands of plates upon the operator's own time may be tedious, but when much work is done an assistant will be a part of the equipment and will at once remove all minor details from his superior. The question of sending out plates to a professional photographer for development will be discussed later.

The beginner without previous photographic experience will first want to know what plates to use, how to handle them, what developer to prefer, and how to use it; how to distinguish and correct defects, and other details. He will also want to know how to prepare a simple " dark-room," and the most important of these points this chapter will aim to teach. For the more obvious mechanical details of photography it is better to have a local photographer take you into his work-room and let you see his supplies and watch him manipulate development. It would take many pages of reading to get the same instruction, and we reserve our space for other features. Any large photographic dealer can furnish the supplies needed for the dark-room.

The Home-Made Dark-Room.—Do not transform a small closet into a working dark-room. The damage to your health and comfort in X-ray work will be almost wholly the fault of a close, stuffy, unventilated, too small exposing-room and dark-room. Allow yourself a room at least ten by fifteen feet in size, and obtain sufficient ventilation to keep the air healthy. The prime considerations of equipment are few. A proper adjustable ruby light, a working table, shelves, trays, and running water are needed besides the chemicals.

The important need is the exclusion of *actinic* light. Rays must not stray in through cracks and key-holes.

Do not understand the word " dark " to signify that the operator must work in almost total darkness. The term is relative rather than absolute. Quite enough " light " can pervade the room for all practical purposes, but the essential requirement is that it shall be *non-actinic* light instead of ordinary illumination. The model dark-room is not really an *erebus*.

A Shifting Ruby Light.—Not the least of the many advantages of an electric-light is the fact that it can be tilted and turned upside-down without spilling oil or reversing a flame. Therefore, a commercial electric circuit in the office can be most profitably utilized in the dark-room.

Fit a plate of proper ruby glass in the top of a wooden box about a foot square, painted black. In the box conceal the low-candle-power electric lamp, using a long and free flexible-cord attachment to the source of current. Run a trolley over the developing table at the height of the head, and from it depend the lamp-box on a rod with a universal hinge. At one corner of the box nail a small handle, and prove by test the light-proof quality of all the joints. Use one of the new pattern of lamps which can be turned down through three or four steps from full incandescence to a mere glow.

In use, with more than one developing-pan on the table at the same time, this box can be seized by its handle and turned light down over the first pan, and next shifted to the second or third, or can be turned partly or wholly away from any or all of the pans. Its red light can be shed in front for the benefit of the operator while only a dark side of the box is toward the plates. It can be run beyond the field of the plates altogether, or can be reversed or turned upward if desired. In fact it is needless to attempt to narrate the many variations of adjustment supplied by this useful box and lamp. The operator who installs it will at once see its great convenience, and will require no further suggestions beyond the hint of the idea.

A Home-Made Safe for X-Ray Plates.—From ordinary five-eighth inch pine-boards have a carpenter construct a box with a close-fitting hinged door. Make it about eighteen inches wide and high and fifteen inches deep, inside measurements. With thin partitions divide the space as a safe is divided for blank-books, the plates to stand on end. The largest compartment will then hold a dozen 14×17 plates, and others will take decreasing sizes down to the smallest used. Lay no plates flat.

Next get from a hardware store two pieces of sheet-lead one-sixteenth of an inch thick. Fit one piece completely over the outside of the box except the front door and tack it fast. Then tack the second layer over the first. Then lead-plate the door. In use keep this safe in the dark-room with its back toward the room containing the X-ray apparatus, and place the latter so that all tubes will project their rays away from the contents of the box. It requires but a little management to so arrange a coil or Static machine that tubes will point in a direction opposite from the dark-room, and this single precaution is a great preservative of plates. The lead casing of the box is sufficiently thick to protect all unexposed plates at distances of more than ten feet from tubes, yet is not too heavy to be moved with ease.

With ordinary tubes placed with their dark hemisphere toward the box the field of safety is much less than ten feet, but it is better to have sensitive films beyond even the suspicion of stray light. Beginners will keep in mind the fact that neither wood, plaster partitions, nor many feet of distance, will protect plates from powerful rays if they are in the path of the rays and are not behind opaque metal as we have described. A plate even partly fogged by proximity to penetrating rays is lost. It is economy to also keep plates cool and dark till used. The *fresher* the film the better the result.

Choice of Plates for X-Ray Work.—Radiographs may be made on photographic papers, films, or glass plates. Every known emulsion has been tried. Good pictures have been made with any and every kind of plate, film, and emulsion. Of the nine leading manufacturers of photographic dry plates in the United States, four so far offer special "X-ray plates," which are more thickly coated than regular films. A great difference of opinion exists among experts as to choice of plates. It is assumed that an expert will prefer the plate to which he is most accustomed, and that with it he will get better results than with a strange plate which may be superior. But an expert ought soon to do the best work with the best plate.

It may be estimated that about 3,000,000 plates were used for radiographs in 1901. As much larger sizes are employed than Kodak amateurs use, they cost much more than would 10,000,000 plates for popular cameras. The incentive to manufacturers would seem quite great, but it is even now a trouble to procure "X-ray plates," and involves delay and often a special order. Therefore, probably seventy-five per cent. of the work is done on ordinary plates. This is not fair to the surgeon, nor does it assist *advance.* Manufacturers should solve the problem of producing a plate with an emulsion of the right thickness and of almost instantaneous rapidity. It should

also be insensitive to the daylight of an ordinary office, so that it can be exposed and developed with neither wrapper nor dark-room.

Tests of thickness of coating have been made. Unsurpassed pictures have been made with a single coating, but it is held that a double coating will afford greater depth and contrasts in average pictures. Experimenters claim that *three* coatings add perceptibly to depth and contrast. Four coatings have been tested, but probably three are sufficient. It is asserted that the maximum result with a triple-coated film shows an astonishing difference over a single-emulsion plate, and that the printed detail is exquisite. Those who have employed multiple-coated plates recommend them as far superior to others.

An attempt to increase the depth and contrast of shadows has also led to the manufacture of films and plates *coated on both sides,* so that the shadow underneath will reinforce the shadows of the upper layer. Some of the best work in the world is done on *double-sided films.* A similar result is aimed at by superimposing two, three, or four ordinary glass plates or films for a single radiograph.

Upon the subject of photographic plates for X-ray work a prominent expert has remarked:

"It was in one sense unfortunate that X-ray light affects bromide of silver in the same way that sunlight does, though to a less extent. Makers have introduced special X-ray plates by using a thicker emulsion or by coating the plate on both sides, which comes to the same thing, but it is the same bromide of silver in gelatine that is employed, and this is so enormously transparent to X-rays that probably not five per cent. are retained by the emulsion, the remainder passing through the plate and being lost. What we want is an emulsion that shall be at once sensitive and opaque, and so retain the X-rays and make them do chemical work. What we want is a plate that shall be as good for X-ray light as other plates are for other lights, and *the ideal X-ray plate will be one that is insensitive to sunlight and which can be exposed without a wrapper and developed without a dark-room.*"

It is generally suggested that the beginner should select any good plate, and then stick to it, as "familiarity will enable him to handle it to the best advantage." While correct in theory, the logic of this idea would retard progress. It is inevitable that improvement will take place during the next few years. *We are approaching the era of instantaneous radiography. All who use plates should be alert to test advances as they are made, and thus promote progress.*

Buy only a half dozen plates of the larger sizes at a time and get them fresh when needed. Do not keep in stock a greater number of plates than you expect to use in about two months. Any plates remaining on hand after three or four months may be good if kept in a cool place and protected, but do not risk an important picture with an old plate. Better throw them away and get fresh ones.

Makers now supply orange and black envelopes to serve instead of plate-holders for X-ray work. When first introduced, in 1896, orders were filled with the plates inserted in the wrappers and sealed, but this is no longer done. In time the inclosed plates deteriorate through unavoidable chemical action of the paper. The envelopes are furnished separately and plates inserted by the operator as needed. Do not keep stock plates long in exposing envelopes.

The great defect in present plates is that X-rays pass so readily through gelatine emulsions that the brief period of photo-chemical action on the silver makes them "slow." The problem is to mix the silver salts or other possible agent in an emulsion that shall be sufficiently opaque to X-rays to hold them in longer action. Makers have indeed tried countless experiments, but harder problems had to be solved before camera photography took its present place, and we may expect the final adaptation of films to the kind of chemical action possessed by the light from a Crookes tube. The true X-ray plate may delay its coming, but it will get here in the course of time and find a hearty welcome.

In England Cristoid films are spoken of as follows by a surgical writer:

"This is a departure from the regulation plate and film, inasmuch as it consists of two films which are so thick that when superimposed they require no support. Therefore, neither celluloid, paper, or other strengthening material being used, they are absolutely free from any texture or grain. They are also non-inflammable and practically unbreakable. They are supplied in boxes of one dozen, each film placed in two light-proof envelopes. In sensitiveness they are as quick as the quickest plates made. Excess of exposure only produces excess density, which may be readily reduced for printing purposes by means of a weak solution of ferricyanide of potassium. In developing, the directions of the makers should be explicitly followed. After the preliminary bath, the negative cannot be scratched and may be handled with as much impunity as a piece of ordinary wet linen. Several may be developed at the same time if each film is thoroughly wet before putting another in the dish. A well-exposed negative may be developed in about six minutes. Frilling is an absolute impossibility. The films may be kept and developed months after exposure. Tropical dry heat does not affect them in the least. Any one having to carry a number of glass plates will appreciate the lightness and unbreakableness of these films."

For these "Cristoid films" Sandell (the maker) claims the following advantages: "Their latitude (of exposure-time) is so enormous that almost any degree of over-exposure may occur without risk to the ultimate result, thus yielding, under these circumstances, an infinitely better differentiation between foreign bodies, lesions, or disease, and the normal surroundings than any other plate or film." It has been stated by men using these films that two pictures of the same part, one given two and the other twenty minutes' exposure, produced equally perfect detail and quality of finished picture.

In Germany the finest radiographs are made on X-ray films of the Schleussner Company, Frankfort-on-the-Main, which, however, are very expensive. A few specialists have imported these films for use in this country, and have deemed them worth the cost and trouble of getting them.

American makers are now producing a film on celluloid which they recommend highly, but American surgeons could no doubt *hasten the coming of the ideal X-ray film or plate if they would unite to demand it of manufacturers instead of following the popular advice to use any plate and "stick to it."*

Bromide Paper and Multiple Positives.—As early as March, 1896, the desirability of getting a positive, or several positives, without being compelled to make a negative and wait for it to dry before a print could be obtained, suggested the use of superimposed layers of bromide paper. Some use the method occasionally, some make frequent use of it and praise its value, while others condemn it.

Developing Solutions.—When the chemical action of light has written the exposed image upon the emulsion of a photographic plate it is still an invisible and transitory writing, and the image must be "developed" to be made visible, and be "fixed" to secure permanency. Therefore, developing solutions and fixing solutions are the photographic "transformers" required to make light-writing useful.

Of the many varieties of chemicals employed in the complex processes of all branches of photography, both acid and alkaline, the radiographer need consider less than half a dozen, and these are all alkaline. It is generally agreed by veterans that no other developing agent so readily imparts all desirable qualities to a negative, and affords such latitude in adapting it to detail and contrast, as pyrogallic acid, familiarly called "pyro." While "pyro" is the best all-round developer, it oxidizes easily and stains the fingers, clothes, and whatever it comes in contact with. Rubber gloves, a protecting outer garment, and certain precautions minimize the drawbacks of pyro and bleachers will wash it off.

Metol and hydrochinon have been for the last few years the popular rivals of pyro. They do not stain the fingers or the film. Metol is said to excel in giving detail and softness, while hydrochinon gives strong contrasts and hardness. Many, therefore, combine the two in a working formula, and vary the proportions of each as required. For, while the quality and quantity of actinic action upon the emulsion dominates the photographic result, yet the *expression* of the result is greatly influenced by manipulative skill in the developing process. With every box of plates sold there is a formula for solutions advised by the maker for that particular plate. When the operator becomes accustomed to managing one solution he is generally advised to make no change till he is sure the change is an actual improvement.

Each developer consists when complete of three parts, a reducer, an accelerator, and a restrainer. The first is to reduce the silver salts and make the image visible. Pyro, metol, and hydrochinon are not only reducers, but density givers, and practically these three agents are all of their class that need to be considered by the beginner in X-ray work. They are the first choice among a legion. But as the intensity of reduction of the oxidized haloid silver salts varies according to the exposure, we need two means of regulating the action; one to hurry it when too slow, and the other to gently restrain it when too fast.

The popular accelerators are carbonate of soda and potassium, which act by "opening the pores of the emulsion" to let the reducing agent into the gelatine so that it can more quickly work upon the silver salts.

The popular restrainer is bromide of potassium, which combines with the silver bromide of the emulsion when the two are mixed, forming a double salt which reduces more slowly than the silver haloid alone.

Do not combine these three agents in a single stock solution. No two exposures being exactly alike, the modification and control of the action of the solution to suit the negative in the tray requires that each ingredient must be proportioned to the needs of the case. Therefore, keep the three solutions in three separate stock bottles and measure out each when needed to be added to the working solution in the tray.

Another ingredient added to the main developing solution is a "preservative," and the one used commonly is sulphite of soda. In mixing developers from printed formula always combine the ingredients in the order mentioned and adhere closely to the special instructions. It is needless to repeat here any of the numberless formula, for

each reader will select his own, but instead of duplicating routines we will present the following communication recently received from Dr. W. L. Kenney, and will allow students to test the merit of his claims themselves.

"The formula given below simplifies development all through so that only the specialist need concern himself about varying the formula for various kinds of work. In X-ray development we desire to so alter the ratio of development as to show in the plate great differences of contrast for slight variations in the density of the anatomic structures. This is accomplished by a very concentrated developer giving dense high-lights, but preventing shadows from participating by enormous proportions of potassium bromide. I believe that the potassium bromide also acts as a reducer, at any rate preventing fog. The ratio of development is certainly altered. The developer is the ideal of compounding, whatever tubes or exposures are used.

"This formula has greatest effect on isochromatic plates, or special X-ray plates which have heavy emulsion with anilin dyes incorporated, thereby rendering plate isochromatic, but also peculiarly sensitive to X-ray and to the restraining power of bromide.

"Hydrochinon	29	grs.
Potassium Bromide	9	"
Sodium Sulphite (crys.)	98	"
Pot. Carbonate (crys.)	187	"
Water q.s. to four ounces.		

(Or, best, because most accurate)—

"Hydrochinon	29	grs.
Sod. Sulph., sp. gr. 1060	1½	oz.
Pot. Carb., sp. gr. 1060	2½	"
Ten per cent. Bromide solution	1½	drachm.

"(The dry bromide can be dissolved in the potash solution so that two and one-half ounces contains nine grains of bromide; the hydrochinon can be kept dissolved in sod. sulph. so that one and one-half ounces contains twenty-nine grains. The whole mixture can be kept united in a bottle that is *entirely* full and corked. It will then keep from two to four weeks.)

"In developing, have temperature of fluids and pans about seventy degrees, and *develop until it is barely possible to see through the bones.* Fix in ordinary fixing bath.

"So developed the negative is superior to any print. Prints are apt to lose finer shadings unless developed (or toned) on principles similar to above. Viewing by transmitted light gives a better effect also. Plates should be developed until you *can hardly see through bones in red light.* They fix out until flesh of leg is barely translucent in negative while bones appear white. A viewing box like a fluoroscope box, or any similar device, is very much better for examination of negative."

The Developing Process.—Experts acquire individual methods. The *beginner* may be instructed as follows: After the exposure of a plate it need not be immediately developed unless it is required at once. The practitioner will naturally in all non-emergency cases put his exposed plates in the lead-closet without opening them until evening, or other spare time permits. The convenient opportunity will ordinarily be obtained within twenty-four or forty-eight hours. Very much delay may possibly injure the plate, but a little delay will not. Some state that if protected properly an exposed plate will keep indefinitely without harm.

When ready to develop go into the dark-room and get out a developing tray, the solutions, gloves, and all necessary things. Light the ruby lamp, turn it very low, rinse the tray, and pour a sufficient quantity of developer solution into the developing tray which contains a "plate-lifter." Then darken the room, open the lead-closet, get out the plate, remove it from the envelopes or holder, and get ready to "wet" it.

A new solution does not readily "wet" a dry plate, but after it has been used once it does so more easily. A very large plate is more difficult to cover evenly and quickly with the solution than a small plate. With the ruby light very low and removed about three feet away, poise the plate flat in one hand with the glass down and the film up. With the other hand, tilt one side of the tray up so that the solution is deep at the side over which you poise the free edge of the plate. Now, carefully lower the plate till it almost touches the solution, drop it quickly and evenly to the bottom of the tray, and at the same instant tilt down the tray so that the solution will flow all over the film as rapidly and smoothly as possible.* Bring up the ruby light and watch for any air-bubble or spot which remains dry, and instantly tilt the solution over it. Then put the light three feet away. With one hand gently rock the plate continuously, so that the developer is kept in motion over all parts of the plate. Bring up the ruby light for better observation after a minute or so has passed, but do not bring it too near nor turn it too high, and do not let too thin a body of solution cover any part of the plate. Keep it rocking.

Watch the plate for the first appearance of alterations and *devel-*

* Or, per contra, some photographers prefer the opposite means of getting the solution over the film. Instead of putting the plate into the solution they pour the solution over the plate. Proceed as follows: Pour out into a graduate enough developer for the plate. Lay the plate film side up on the bottom of the dry tray. Hold the tray on a slant and from the highest end quickly pour the developer out of the graduate over the film. Rock the tray at once so as to spread the solution and wet the entire film. Then proceed as taught. By this method a plate can be treated with less developer than by the other plan.

opment of the picture. This may begin in less than thirty seconds, or may take much longer, according to the nature of the exposure and the activity of the solution. Note when the borders of the plate grow darker, and the first indications of the image appear. To acquire experience with your first plates then lift the plate by its edges from the tray, and hold it up in front of the ruby light. Turn both sides of it toward the light to study the back and front with *transmitted light* during the first stage of development. For this purpose pass it quickly up close to the light, but get it back again into the tray as soon as possible to avoid fogging it. After some experience the operator will not need to do this until nearer the end of the process, but at first it contains important instruction.

If the dark area spreads *rapidly* and the denser shadows appear very quickly, the development is going on too fast, and before finer and deeper shadows could be brought out some of the plate would be *over*-developed. If this is the case, lift the plate just out of the tray, quickly pour in a few drops of the *restrainer*, rock the tray to mix the solution, and replace the plate. Then proceed as before.

If the shadows come too slowly for the quality of exposure, lift the plate, add *accelerator*, rock, and mix, and return the plate.

Continue rocking the tray and watching the plate, with a view to regulating the proper strength of the developer to suit the requirements of the exposure. The time required for a normal development will be less in summer than in winter, and is also affected by the part of the body exposed. Continue the development until the film side is entirely dark, and again examine it by transmitted light. Hold it about ten inches in front of the ruby lamp, with the light turned up to the limit of safety. If it still transmits light, return it to the tray and continue to rock the solution. When still blacker, examine it again and if you can see no picture at all, but find the plate practically opaque in front of the ruby light, consider the development finished.

A normally exposed ordinary plate may develop properly in five, seven, ten, or fifteen minutes, according to the manipulation of the solutions. If the plate is *over-exposed* it will turn dark as quickly in a weak developer as a properly timed plate would in a stronger developer. If the plate is *under-exposed*, a normal solution will darken it very slowly. If the rays have acted so little on the plate that the developer has almost nothing to work on, the image may not appear even after fifteen minutes in the tray. If this is the case it indicates that the developer must be proportionately strengthened, and if the final result is too thin and weak the plate may be thrown away and a new exposure made.

If the beginner develops a hand on his first plate, and a pelvis on the second, he will be greatly instructed in the different rendering of the image as he observes it during the development. The plain outlines of the hand will delight the beginner, while the obscurity of the pelvis from first to last may discourage him into thinking that the plate is a failure.

The art of developing is not learned in a day, but if all plates were so exposed as to be chemically prepared for *normal* development there would be no difficulty about it. *Demands upon skill are made by variations in the degree of chemical action, and by peculiarities of both photographic and surgical conditions.* "Practice makes perfect," however, and in a reasonably short space of time the novice can do about all that his needs require.

One of the most difficult things for the beginner to determine is how far to carry the development of a given negative. The extent to which negatives lose *density* in the *fixing bath* varies with the length of exposure, with the density of the part photographed, with the age of the subject and particular part of the body exposed. Experience cultivates the operator better than descriptions. Ordinarily, thin parts of the body do not require as dense development as the thicker parts. When examined by transmitted light, the hand or foot need not be carried to the point of invisibility, while with the thicker parts development should not stop *until the negative is black and without a trace of detail.* Developed to this extent the image will usually fix out to the required strength and show the desired result. When softness of contrast between dense and less opaque tissues is desired, the developer should be weakened considerably and the process slowed. When near the end of development watch for commencing *fog.* Stop before the fog increases.

The development of films with *two sensitive sides* will require a pan much larger than an ordinary plate of the same size. A five by seven film should be developed in a seven by ten inch pan, and at least fifty per cent. more solution should be used than would be needed for a plate. Not only watch and rock the tray as usual, but reverse the films frequently to secure equal action upon both sides and to avoid the adherence of air bubbles. Slightly bend one corner of the film upward and another corner downward, and they can be handled in the developer without trouble. Or, a clip can be used.

In the fixing bath reverse double-sided films frequently for the same reason that they are reversed in the developer. The same principle applies to the use of glass plates which are coated on both sides. In drying double-coated films suspend them by clips in the manner usually adopted in drying paper prints.

Developing Practice for Beginners.—Take two small plates, 5 × 7, wrap in the usual light-proof envelopes, and place them side by side under a tube focused at twenty inches from the line between them. With the right and left hand of any person separately on these plates, make a normal exposure. Then take the plates to the dark-room. In a single tray develop both plates at the same time, with the same solutions, in exactly the same manner. When one plate has become moderately black on the back when held between the eye and the ruby light, take it from the developer, rinse it well in running water, and put it in the fixing-tank. Develop the second plate still longer until it becomes considerably blacker by transmitted light or entirely opaque. Then rinse and fix. Remember carefully the appearance of these two plates at the time development was arrested. When fixed and dried *compare the results.* Have a *print* made of each, and compare the prints. Note the superiority of the last plate over the first.

By making a few practice studies of this kind, the student will instruct himself to know what degree of development yields the best final result. The instruction thus gained has no relation to the number of minutes the plate may be in the solution, for the factor of time will vary with the *quality of the exposure.* The beginner will be more likely to *under*-develop than to *over*-develop, but by carrying these tests through a considerable range of preliminary trials, the operator will most quickly ascertain when he *has got all out of a plate there is in it.*

Fixing.—At the close of development the plate is not yet ready to endure daylight. The residue of chemical salts must be removed, and all further changes arrested. This process is called *fixing,* and the routine solution is called "hypo" for short. Do not put the plate directly from one tray into the other. Hold it under the cold-water faucet and rinse it on both sides. Then drop it into the fixing bath and cover it from light. Always have the film side uppermost if using a flat tray, but the best fixing bath holds the plates edgewise in vertical grooves.

During *fixing* the tray does not need watching or rocking, and it requires from twenty to thirty minutes to thoroughly complete the process. When the film of the plate is first put into the hypo, it is white to *direct* observation, although black to *transmitted* light. In the hypo the white is eaten away, and gradually becomes black. Until the last trace of white disappears the plate is not fixed. It does no harm, but is well on the safe side, to leave the plate an extra five or ten minutes in the hypo. If taken out too soon, it will in time stain yellow and deteriorate. Use the formula supplied with your plates.

Washing the Plate.—The final finish of the plate consists in washing it. Do it *thoroughly*. The thoroughness with which a surgeon washes his hands is not less complete than the thorough washing a plate requires to cleanse it from lingering chemicals. For this reason, and to avoid tax upon the operator's patience, an *automatic* washing process is indispensable. Lift the plate from the hypo, rinse it in plain water, and, if in no hurry, put it in the washing tank with running water and let it alone for a couple of hours. Then remove it, place it in a drying rack, and let it dry at its leisure.

If the picture is wanted in haste hurry the washing by gently rubbing the film with absorbent cotton while holding it under running water. A plate can be hurried through the washing process in twenty minutes or less, by the personal attentions of the operator. It can then be dried very quickly (in half an hour or less) by placing it in a dry-room in front of an electric fan. Until the plate is thoroughly dry it is not ready to file, but can be examined for diagnosis, if necessary, before these final steps are completed.

Studies in Defects.—When the beginner has his first completed negative before him he will ask whether it is a success or failure. Between the two may fall much of the early work of the novice, and, to assist him in recognizing wherein a plate varies from success, he must study the more common faults and how to rectify them. Photographic primers, which may be had at any supply store, give the routine directions for treatment. After reading them go to the darkroom with some practical friend and see him demonstrate the procedures. We leave the subject here for matters of far greater importance in which instruction is much more difficult to obtain.

Prints from Negatives.—In general the negative is the basis of diagnosis. Prints do not always seize every detail of the negative nor do they afford information by transmitted light. Occasionally a print may give some information that was overlooked in examining the negative, and for distribution, public exhibition, and various other reasons the making of a print is a natural corollary to the radiograph. For fine detail, and especially for reproduction, the print should be made on a glossy paper. Matt papers are not suited to X-ray pictures. A good negative will make a good print on almost any good paper, while a poor negative cannot be made good by any

kind of paper. The choice is somewhat affected by the intended purpose for which the print is made. If the beginner takes up the subject of printing it is easy to sample various kinds and suit his own taste. If the negative is turned over to a photographer for printing, he will be apt to use the papers he has in stock. Special papers are continually being introduced, and samples and information concerning them may be obtained from photographic supply stores.

As any single print from a negative may vary from another or show less than another, it is best to make several prints in important cases if the diagnosis is not made from the negative and a print is needed. All who have had their portraits taken will recall how various the effects of a dozen prints may be.

Who Shall Do the Surgeon's Developing?—Is there need of experience in photography in order to become an expert in radiographic work? That depends upon what the radiographer *desires to accomplish*. Many a man who never pressed the button of a Kodak has made good X-ray pictures, and many a man has succeeded in developing, washing, and fixing his first X-ray picture without any previous knowledge of the dark-room. But unquestionably "knowledge is power," and the student of photo-chemistry can soon surpass the surgeon who simply exposes an X-ray plate and develops it by the formula printed on the box.

Along with this question is the important one, "Who shall do the surgeon's developing?" So much depends on the development of the X-ray plate *by the man who alone knows what anatomical shadows he is aiming to bring out* that every operator must do this part of the work himself, or have it done at hand by a trained office assistant who participates in the handling of the patient; or an outside developer *must be told the nature of the case and what is expected from it.* There is hardly any disagreement on this point among practical workers who seek diagnostic results and not merely exhibition pictures. They not only feel the necessity of submitting to the tax of the dark-room, but it is obvious that to fail to do so is to lose part of the instructive information to gain which the radiograph is made. The argument that it is a great advantage for the physician to develop the plates himself and thus be able to learn the results at once instead of losing time by sending the plates to a photographer, is not the great argument that takes the operator to the dark-room and keeps him there with the devotion of an enthusiast. He soon learns that diagnostic developing requires a knowledge of the case, and the condition exposed, and he who does not possess this knowledge cannot know what his plate is doing. Moreover, it is work that is full of interest, and every true artist is an enthusiast.

Some surgeons have felt that a skilled photographer should be able to develop their plate much better than themselves, and this would be true in cases of no previous experience provided the photographer could be supplied with what he usually lacks, viz.: the surgeon's training in anatomy, pathology, diagnosis, and X-ray shadows. The best plan is for the surgeon to let an office assistant study what is needed of photography, and then have this assistant make the exposures and do the developing under the surgeon's direct supervision.

Over and over again beginners have thought to save the trouble of developing, have carefully made adequate exposures, and sent the plates to a professional photographer only to be told a day or two later that there was *nothing on them.* This has repeatedly happened to me during an emergency when my own facilities were interrupted. Amateurs with the ordinary camera have the same experience.

While it has been well said that failures in scientific work are often the greatest and most efficacious teachers, yet a photographer's failure to develop a plate correctly will teach nothing to the surgeon. A knowledge of what to avoid is likewise of great importance, and without more or less knowledge of photography the X-ray worker will lose valuable experience and advance slowly.

Possibly the question of *development* may ultimately prove to be one of the most important in X-ray progress. There are those who think so. The camera photographer will note the great difference in the proportions of restrainer which the experience of several years has taught radiographers to use. The camera photographer seeks a different sort of picture. He want soft lights and half-tone; radiographs seek contrast of densities. His negative is made with reflected light; the radiograph is made by transmitted light. He knows three grades of light in the negative—high light, half-tone, and shadow; the radiograph knows but two, half-tone and shadow. The radiographer instructed by experience puts into his solution five times the alkali and ten times the bromide used in portrait work and uses more reducer. The routine professional cannot comprehend the rationale of the X-ray developer, and often looks at some of the formula aghast. But it may be that in the near future still more suitable combinations can be worked out which will lend to images qualities that are so far lacking in radiographs.

CHAPTER XV

SELECTED OPERATIVE TECHNICS

Technic for Radiograph of the Carpus. Methods for Spinal Exposures. Technics for the Œsophagus. How to Remove Coins from the Œsophagus. Pelvic and other Measurements. Special Hints. To Preserve Contour of Soft Parts. Sinuses. Technic for Foreign Body in Eye with Davidson's Head-Rest. General System for Position of Patient. Technics for Chest Fluoroscopy. Intercurrent Radiography During Fluoroscopic Inspection. Technic for Cardiac Exposures. Exposures of the Chest in Pulmonary Cases. The Rheotome Method. Technic of Instantaneous Thoracic Radiography. Studies in Same.

To secure that mastery of technical methods in their entirety, which will at once enable the operator to adapt the most convenient as well as the correct technic to any given case, the general subject as taught in these clinics should be studied as a whole. Certain principles noted in one chapter will often be applicable in other directions and other branches of work; therefore a complete reading of the entire course should begin the special study of any particular department of X-ray practice. Having done this we will now take up the study of such selected operative methods as will specially impress local procedures on the mind and simplify some of the most important details of daily needs.

Technic for Radiograph of the Carpus.—To secure the most complete information regarding an injured or diseased part, it is the rule to also make an exactly similar radiograph of the opposite normal part for purposes of comparison.

First Method.—Prepare two five by eight films or plates in the usual wrappers. Place the author's Position-Finder on the stand or table at the convenient height for the patient. Centre the tube at twenty inches vertically over the indicated centre as marked on the metallic base. When ready to excite the tube for the exposure, bring in one plate and place it on the base which automatically locates its centre directly in the axis of the ray. Upon the plate now place the injured carpus with the centre of the diagnostic field as indicated by the clinical examination, and previously marked on the skin, directly upon the marked centre of the negative, so that *the long axis of the part is at right-angles to a line drawn across the centre of the plate.* Make the exposure as usual, remove the part and plate, bring in a second plate, and place the other hand in exactly the same position on it. Repeat the exposure. Develop both plates with the same treatment, and for study lay them side by side on the examining-box described elsewhere.

It will be seen that this method does away with much of the trouble of techniques ordinarily described, which direct the operator to first place the part upon the negative and then adjust the tube with relation to the part. A single large plate can be used, if preferred; the first hand being taken on one-half of it while the other half is protected during the exposure by a sheet of lead. As a very slight change in the relative position of the wrists in the two exposures will produce an equal difference in the radiograph, the importance of automatically and instantly locating both plates in exactly the same position and centrally under the axis of the rays, is obvious. By also using the author's distortion landmark, the proof of an axial exposure or any deviation from this will be shown in the negative beyond dispute.

The method of early days of placing both hands side by side upon a plate and placing the tube over the line between them is too inaccurate for diagnostic purposes. One thing at a time is all that can be rightly done, and it is impossible for the correct axis of the rays to be in two places at once. To properly radiograph one diagnostic field at a time must suffice.

Second Method.—Remove the depthing rod from the author's examining frame and level the markers. Secure an axis of the rays in the right-angle at the foot of the markers. Insert the part so that the centre of the diagnostic field will press against the point of the front marker. It will then be exactly in the axis of the rays and be imaged without "distortion." Next slip the photographic plate between the part and the frame and proceed as before with the exposure. A second plate with the normal carpus for comparison is next readily exposed in the same manner. The correct axis of rays is maintained by the frame for as many exposures as may be desired. The tube needs no changing when once stationed, and the frame is levelled to its focus. The entire technic presents a maximum of accuracy with a minimum of care and trouble. The same method applies equally to exposing the elbow, shoulder, or any exact section of the upper extremities. It is of universal convenience and application.

To keep the shadow of the markers from the negative simply slip the rear bar aside during the exposure. The act of placing the plate inside the front marker prevents its appearing in the picture. If either marker (or both) is required in the negative for landmark purposes simply leave them in position and place the plate outside the front of the frame instead of within it. If a circular outline of the small field is desired to show in the negative change the rod markers to the pair of *rings* and proceed as directed before.

Methods for Spinal Exposures.—Luxations and fractures, scoliosis, congenital anomalies, ankylosis, tumors, especially gummata, tuberculous spondylitis, etc., have all been repeatedly diagnosed by the aid of X-rays. The posture of the patient will depend somewhat upon the location and suspected character of the lesion. Spinal bones, when placed in closest contact with the plate, will show nearest life-size, and in some respects will thus yield the best definition. If radiographed at a distance from the plate so great as the thickness of the body the relative enlargement and diffusion of the shadows will vary according to the mass of the individual and the distance of the tube. The effects obtained with a little child, or an emaciated adult, with the abdomen on the plate, will be in striking contrast with a radiograph of a corpulent man with the tube at the same distance in both cases.

The cervical vertebræ may be radiographed anteriorly or from either side. For special local pictures of the neck use a narrow plate which will fit in and press closely in contact with the part.

The dorsal vertebræ may be radiographed anteriorly or at a right or left oblique angle.

The lumbar vertebræ may be radiographed in either anterior or posterior position.

No great *extent* of the spine can be *correctly* radiographed on a *single plate*, if the object is to show the condition of local vertebræ. By reference to the author's divergence chart, accompanying this book, it will be seen that practically but one vertebra will occupy the exact field of the central axis of the rays, and that with the tube at twenty inches only one additional vertebra above and below the axis-centre (three in all) will be defined with a *minimum* of departure from a right-angled shadow. Above and below these correct diagnostic fields the slant of the rays will cause increasing overlapping of the shadows and lessen the value of the picture in proportion to the distance from the centre.

In making a radiograph with a view to observing conditions lying in front of the spine near the anterior wall the patient should always be placed face downward for two reasons: by removing the spine to the greatest distance from the plate its shadow is thinned and spread apart, and by bringing the object for diagnosis nearest to the plate its shadow is concentrated and best defined.

For *recumbent* exposure centre the plate with the author's Position Finder first laid on the table with the tube over it at a minimum of twenty inches. With an efficient tube the distance may preferably be thirty inches if the subject is thick and the avoidance of even a small degree of magnification is desired.

Mark the centre of the plate on the envelope wrapper and mark the skin at the site which should be aligned in the exact axis of the rays. Then place the patient on the plate with the marked spot in contact with the marked centre on the envelop, and all is ready for the exposure. No other adjustment is required. Make the exposure and proceed as taught.

For *erect* positions use the author's examining frame to secure the path of the axis of the rays. Level it with the marking rods in the middle of the frame. Mark the centre of the envelope wrapper. Put the plate in the frame so that the glass back presses against the front posts and the marked centre agrees with the front axis-marker. Then slip in the patient so that the marked spot on the skin (the centre of the field to be skiagraphed) presses against the plate on the marked centre. Slip off the rear marker to keep its shadow off the plate and proceed with the exposure as taught. Any number of plates can be set in the same position for duplicate exposures without changing either tube or frame. The mechanical simplicity of the technic is perfection. A right-angled picture must always result from this method, as there can be no "distortion" when the part is radiographed in the exact axis of the rays. This fact cannot be too strongly impressed upon the mind.

Technics for the Œsophagus.—The least satisfactory technic for the detection of foreign bodies in the œsophagus is that which places the tube directly behind the spine and the plate or fluoroscope in front of the sternum. Avoid this.

Seat the patient upon a sufficiently high stool with all superfluous clothing removed from the trunk of the body. Adjust the tube at the level of the field to be examined and start it into action. Now partly turn the patient so that the fluoroscope is in relation to the right side of the front of the body while the rays come from the left of the spine behind. This *oblique* position of the body *will carry the shadow of the spine to one side of the line of œsophagus so that foreign bodies in its canal are projected on a clear field.*

The following aids to the diagnosis of stricture of the œsophagus are combined with this technic:

1. Have the patient, at the time of the examination, swallow two drams of bismuth in about four ounces of water. If a tight stricture exists the water is stopped at the point of constriction, the bismuth settles against the walls of the œsophagus, and the shadow is readily observed with the fluoroscope.

2. When actual stenosis does not exist as tested by the solution have the patient swallow a capsule or wafer of bismuth (or containing a shot) while the examiner inspects the chest with a fluoroscope. If the result is positive the shadow will be seen either stopped and remaining in the same position for some time, or else moving downward very slowly.

3. When the failure of the above methods demonstrates a still larger calibre of the stricture have the patient swallow some article of food which he knows from experience will lodge, and then on top of this swallow the loaded capsule and the fluoroscope will complete the diagnosis.

In the case of a spasmodic stricture the behavior of the tissues in speedily rejecting the capsule or whatever was swallowed would point to the character of the lesion. After examinations with a fluoroscope a radiograph can be taken if desired. If difficult to obtain a view in other positions, turn the patient more sideways to the tube and incline the body toward the tube. Then press the fluoroscope high in the axilla with the shoulder elevated as much as possible.

How to Remove Coins from the Œsophagus.—Edwards reports:

"During the last two years eighteen cases of coin in the œsophagus have come to my notice. In five of them the coins have been lodged for periods varying from five weeks to three months without serious consequences. They were all situated in the same position; namely, on a line with the top of the sternum, and the face of the coin was in each instance turned forward. With the exception of the first case which came to my notice, and which was removed by operation, they have one and all been removed by means of the coin-catcher within a few minutes of their positions being ascertained with the X-rays.

"It is a pleasure to be able to praise a surgical instrument which is generally believed to be useless. This instrument (the coin-catcher) is absolutely certain to achieve the results for which it was designed if properly used. It consists of a whalebone stem in the ends of which is fixed a piece of watch-spring. On the ends of this, on a loose hinge, is fixed a miniature anchor which moves freely from one side to the other. When this is passed down the œsophagus, which contains the coin, and past the obstruction, one of the free arms passes beneath and behind the coin, so that when the instrument is withdrawn one arm grips the coin and brings it up.

"Until the discovery of the X-rays the coin-catcher was generally held to be a useless instrument, many surgeons preferring to operate rather than to try it. The positive knowledge which is gained by means of the fluorescent screen has, however, taught us that it can render invaluable aid. In several cases which have come under my notice the coins have been in the œsophagus for a lengthy period with but slight apparent discomfort to the young patients, hence there existed much doubt as to the presence of a foreign body at all, and it was only after the application of the X-rays that the diagnosis was made a matter of certainty.

"The difficulty in all cases in ascertaining the presence of a coin without the X-ray leads me to ask: What became of such cases before the X-ray? In all probability many patients died without the exact cause having been discovered. A coin left undisturbed would undoubtedly slough through into the trachea and the patient would die from a septic pneumonia. I have no doubt that many lives have been spared by the use of the X-rays, and have no hesitation in recommending the coin-catcher as a most useful and most efficient instrument."

Pelvic and Other Measurements.—When observed on the fluorescent screen or fixed on the negative plate any shadow of an object is magnified in proportion to its distance from the screen or plate, and the space between it and the tube. To reduce the shadow to the true dimensions of the body ordinarily requires some figuring.

It is sometimes desired to know the real size of a bullet or other foreign body buried deep in the tissues and an example of references to the reduction of pelvic enlargements is the following, taken from the *British Medical Journal:*

"The authors place the patient horizontally over a plate twelve by sixteen inches in size and adjust the tube vertically over the centre at twenty inches height. The exposure is then made and the plate developed. The shadow of the pelvis is measured, and as the distance from the tube to the plate is known the pelvic dimensions can be accurately computed. To facilitate this Levy has designed an instrument on the principle of the pantagraph by which the true conjugate can be mechanically determined. The transverse diameters at the brim and outlet can be estimated with equal certainty, and the method has been satisfactorily tested in Landau's clinic."

The automatic and graphic reduction of magnified shadows to their just proportions is one of the functions of the X-ray Divergence Chart which supplements this course. The process has the advantage that it requires no computations or figuring of any kind.

In the case of a bullet, and taking twenty inches from the anode

focus to the centre of the plate as the standard working distance, make the radiograph as usual. Get the depth of the bullet (also without figuring) by means of my examining frame, and the two red lines which mark the width of the shadow at the twenty-inch cross line show the true width of the object at its height above the cross line. A pair of dividers may be used to take the diameter of the shadow, or a strip of paper may be laid on the negative and a pencil mark made at the centre of the plate, and at each side of the shadow of the bullet. Lay this strip on the twenty-inch cross line and a glance up the two red lines to the equivalent of the depth of the bullet, say two inches, will instantly reduce the diameter to that of the object sought. The measurements are self-evident and are made at sight.

Having a negative or print of the pelvis taken at the standard distance of twenty inches, the twenty-inch cross line of the chart shows the dimensions of the magnified shadows. To reduce them to normal the cross line at the height of the brim above the plate will show the true diameters. By centering one leg of a pair of long dividers on the central line of the chart and spreading the other point till it reaches the red line which marks the true brim, we obtain a correct radius. Then place the dividers on the print or negative with one point at the centre and mark a circle. This circle will indicate the proportions of the brim reduced to actual size.

Whether determining diameters at the brim or outlet the deviations from a horizontal plane can be corrected and the true diameters read at sight on the chart by taking the readings from the converging red lines at the distances above the twenty-inch base line, which agree with the actual perpendiculars of the pelvis being measured. By a few moments' use of a rule, a pencil, and pair of dividers, a print of the pelvis can be marked with circles at the brim and outlet, and with cross diameters which shrink the shadows to the size of life. The dimensions in figures can be written on the lines and a permanent record obtained. Those particularly interested in the subject could no doubt work out other details.

Some aim to get the unmagnified size of the pelvic brim by covering one-half of the plate with lead, placing the tube vertically over the edge of the opposite side and taking the half in one radiograph; then repeating the process on the other half. The result may or may not be satisfactory, but requires two exposures and yields a broken picture. A single exposure with a centrally focussed tube produces an evenly magnified shadow which the Divergence Chart instantly reduces to normal size. Mere mention of the two methods suffices to show which is best.

"The value of the X-ray in obstetrics," both during pregnancy and in the absence of gestation, has been investigated by Dr. Mullerheim, who maintains that by their aid the various forms and degrees of pelvic deformity, such as arise from rachitis, esteo-malacia, and spondylolisthesis may be detected and appropriate treatment instituted in case of subsequent pregnancy. He says:

"It is possible by this method to determine accurately the distance between the posterior superior iliac spines, the breadth of the os sacrum, the distance of the lumbosacral crista spinosa from the posterior superior iliac spines, and the distance from the middle of the promontory of the sacrum to the sacro-iliac symphysis. Not only can the presentation of the fœtus be determined, but also the size of the fetal head and the dimensions of the pelvis."

Freund has found that placing the patient in the Trendelenburg position was a great improvement in radiographing the pelvis, as then the vascular intestinal coils fall toward the abdomen and to some extent the field is more clear for the passage of the rays.

To Preserve Contour of Soft Parts.—In making stereoscopic or even plane negatives of any part of the extremities with a view to present the bones in relief within the rounded body of the tissues, it is necessary to preserve the muscle-masses from over-exposure. To preserve the outlines of the arm or leg while showing the interior bones so that the parts have the surface contour visible fill the meshes of a roller bandage with bismuth powder and apply to the part. The bandage will assist in holding the image of the surface contour while the bones are being penetrated. Make sharp, quick exposures.

To make the negative show fine markings of the skin of any thin part moisten the skin, dust on the surface a little bismuth powder, and partly wipe off the surplus. Then make a short exposure.

In all exposures with a view to showing the soft tissues plainly make short work of it, and have the tube neither too close nor too penetrating. It is not easy to lose the shadow of a bone by over-exposure, but it is very easy to lose the best effects of soft parts by too much penetration of the rays. A little experience is the best teacher as to exposure-time.

Sinuses.—To demonstrate the course and extent of sinuses and abscess cavities in a radiograph when they are accessible for injection, inject into them a solution of one part of bismuth subnitrate to two parts of glycerine. This will cast a darker area of shadow than the adjacent soft parts. Even water will cast a shadow among soft parts and may be used to inject a sinus. Iodoform has been used, but is open to objections for some purposes.

Injecting Arteries for Radiographs.—In anatomical studies of the circulatory system excellent results have been obtained by injecting the body with a mercurial salt, and also with heated compounds of triturated Chinese vermilion in a fatty base which hardens on cooling. Many studies have been made by special workers with a view to class instruction. The smallest vessels show beautifully in the negative when injected with a fluid opaque to the rays.

Gaseous Inflations of Hollow Viscus.—Air is much more transparent to X-rays than any tissue or fluid of the body, and, reversing the principle of injecting a dense compound, we may inflate certain hollow organs with transparent gas, and thus make a light contrast with denser bodies around them.

The intestinal tract offers the chief field for this method. The stomach may be distended both for the purpose of detecting a darkened area by contrast if part of its wall is thickened by disease, or to remove or define its borders to observe conditions about adjacent parts, such, for instance, as the pancreas. If the stomach and lower bowel are inflated the outline of the spleen is better defined by its contrasting density. The rectum, sigmoid flexure, and descending colon may be traced when distended with air by their light course amid darker surroundings and in addition to direct effect on the inflated gut the examination of adjacent organs, as the left kidney, may be facilitated by the contrasting lightness of the margins. An internal tumor also may suggest that the lower intestines be inflated to bring out the darker shadow of the solid body. Refinements of these kinds in X-ray examination belong to the work of the expert, and are useless till skill in interpretation of shadows is developed.

Technic for Foreign Body in Eye with Davidson Head-rest.—The object of this head-piece is to secure the absolute immobility essential to the localization of a pin-head body in the eye.

Place the frame on a table at such a height that the head of the patient sitting comfortably in an ordinary chair will adjust itself to the side of the frame, right or left, as the case may be. With a piece of adhesive plaster secure a section of fuse-wire one centimeter long in the centre of the lower lid—vertically—so that the upper end has a known relation to the eyeball. This furnishes the base from which the location of the buried body is found. Next fit the side of the head with the injured eye flatly against the window of the frame which receives the plate, so that the horizontal metal rod crossing the field of the window will be on a level with the lower lid. Next adjust and screw fast the chin and head clamps so as to hold the head *fixed* in the secured position. Connect the tube in the arm of the frame which slides horizontally to the plate and focus the rays at right-angles to the point where the cross-wires of the window intersect. Measure the distance exactly. See Plate No. 14.

Test the working of the tube, cut out the current, and bring in one 5 × 7 plate in the usual wrapper. Insert the plate in the open window and close and clamp fast the hinged-door so as to press the film well up to contact with the temple. When all is ready for the exposure instruct the patient to close the eyes and direct the vision to a small point some feet in front, level with the horizontal rod and parallel to it.

Now quickly move the sliding-arm of the tube-holder three centimeters to the right of the previously centred focus and make the shortest exposure which the capacity of the tube will permit. Less than a full minute is best. As soon as the first exposure is made cut out the current and quickly shift the arm holding the tube to a position three centimeters to the left of the central focus, which will be six centimeters from the focus at which the first exposure was made. Then on the same plate and with no change of the patient, keep the eye in the same visual axis and make a second exposure equal to the first.

Cut out the current when done, remove the tube, unclamp and release the patient, let down the door of the window, and take out the plate on which the two exposures were made. Develop the negative in the usual manner, and it is at once ready for the final step of localization. Two separate plates are used when a stereoscopic picture is desired, or two can be used always instead of one as described.

To determine the results employ the cross-thread apparatus as elsewhere described; then place the patient facing you in the exact position he occupied when skiagraphed, and apply the measurements made on the plates. The foreign body will be the measured distance to the nasal or temporal side of the upper end of the external fuse-wire, the measured distance up or down, and the measured distance backward from the point arrived at parallel to the visual axis. The trained ophthalmic surgeon can at once show the situation on an eye-chart and can cut down and remove the particle of steel as precisely as if it were a bullet in the leg. As done by the expert it demonstrates the limit of scientific precision in localization and is quickly done, but the novice or one who is not trained in ophthalmic work will be puzzled to use his pictures after he has made the exposures *secundum artem.*

Davidson has personally demonstrated the marvellous accuracy of his method in more than 300 cases, some of them locating pieces of steel so small as to be scarcely visible to the eye and

often buried in opacities that would have defeated search for them in any other way. He has made eye-work as precise an art as the measurements of a surveyor.

General System for Position of Patient.—To render the interpretation of radiographs easy, and to avoid as much as possible distortion of the shadows, a London surgeon makes the following suggestions relating to exposure technics:

"1. There should be certain points on the human subject over which the anode should be placed, and on the negative a small mark should denote the position of the focus.

"2. The distance from the tube to the plate should never be less than eighteen inches. (Twenty inches would be a good general standard.)

"3. In radiographing the lower extremities they should be placed at a right angle with a line drawn between the two anterior-superior spines of the pelvis, and the spinal column should be absolutely at right-angles to this cross mark.

"4. In the upper limbs: for the shoulder-joint, the arm should make an angle of forty-five degrees with the mid-line, and the hand should rest with the palmar surface downward. The opposite sound part should always be shown for comparison, taken, of course, under exactly the same conditions. In the elbow-joint the internal condyle being on the film, the anode should be placed over a point about an inch below the external condyle in the line of the forearm. This is for the purpose of opening up the joints as much as possible.

"5. For the trunk, it should be placed as symmetrical as possible, and for the cervical vertebræ the best position is with the occiput well over the end of the film or plate and the chin high up, but exactly in a straight line with the sternal notch. What is really needed is that all X-ray workers should have a fair knowledge of anatomy, especially of bones and joints, and have *a system of uniformity* for skiagraphing the several parts of the body. This system should be known to surgeons in general so that they will be able to adequately interpret the works of any particular operator."

A *System* of almost universal applicability and of a mechanical simplicity comparable with that of focussing an opera-glass is presented in the author's Examining Frame. It makes no complex demands on technique. It taxes the memory with no cumbersome details. It does not require the mastery of different methods for different parts of the body. It is adapted both to exposures in the perpendicular and at any angle outside the direct axis. It involves only two acts:

1. The securing of the field of rectilinear radiance. The act of levelling and sighting the frame does this almost instantly, and, once levelled, the frame holds the field for any use *on any part of the body.*

2. The placing of the part in the field in the frame.

The act of placing the part in the frame is almost as simple as putting the foot into a shoe. We assume that the examiner starts out by knowing what part of the body he wishes to examine; that he can conveniently locate and mark the exact spot on the nearest surface of the patient's skin; that he can put that spot exactly on a marker in the frame, just as he could put one penny on top of another; then, having done this, the relation of the opposite surface of the part and the focus of the tube need no plumb line or attention whatever for they fall automatically into their correct relation with the entire part through the mere act of placing the part in the frame. Study of this simple method will repay surgeons.

Technics for Chest Fluoroscopy.—The examination of the thorax with a fluoroscope with the patient sitting or standing is divided as follows:

1. *Anterior inspection.* Screen in front of the thorax.
2. *Posterior inspection.* Screen upon the back of the patient.
3. *Right lateral inspection.*
4. *Right anterior oblique inspection.*
5. *Left lateral inspection.*

Remove all superfluous clothing from the trunk of the body. Adjust the fluoroscope in the examining frame. Arrange the tube so as to leave four inches space between the tube-wall and the surface of the patient's body. Level the tube and frame to secure the fixed diagnostic field as taught. Have the patient erect, either standing or sitting. Next bring the patient's thorax within the frame and field, and in close contact with the fluorescent screen. While pressing the fluoroscope against the patient, with one hand outside the field press the patient forward upon the screen so as to secure the best possible contact. Either by regulating the action of the tube or by *increasing the distance between the tube and the patient* secure first the degree of illumination which affords the best contrast of shadow with the given case. As no two cases are alike in substance, thickness, density, age, etc., the regulation of the illumination of the screen is of primary importance.

Beginning with one apex gradually move the entire area to be examined through the bounded and stationary diagnostic field, which does not change its position or deviate from the axis of the rays during the entire process. Any one who has witnessed the random and unscientific inspection of the chest in the ordinary manner will appreciate the precision imparted to the process by the fixation of the fluoroscope, the diagnostic field, and the axis of the rays. During the steps of inspection have the patient at one time make deep *in*spiration and hold the breath as long as possible, so as to keep the organs still. Next, inspect during forced *ex*piration. Also during regular *deep* breathing and regular *average* breathing. Also with the arms in different positions, especially with them both *extended upward over the head to clear the upper regions of the lungs from the shadows of the scapulæ.* These clinical posturings during the examination must be directed by the physician according to the object of the examination, and experience will suggest those best adapted to different cases.

While noting that the excursion of the diaphragm is altered by any state of disease that limits expansion remember that the normal dimensions of the chest vary, and that a short chest will have a shorter rise and fall of the diaphragm than a long chest. Allowing for this normal difference have the patient sit still and breathe quietly, and then mark on the skin of each side the high and low limits of rise and fall. Then have the patient take several energetic and deep breaths. Immediately mark the maximum rise during forced expiration and the maximum descent on deep inspiration.

In observing bones or bullets with the fluoroscope the degree of radiance employed may vary within wide limits and yet permit the diagnosis. Not so with examinations of the thorax. Faint shadows which can be caught with just enough light may be lost with too much or too little. Therefore, during the view increase and diminish the dosage of the tube to cover every possibility of shadow detection. For this purpose it is convenient to arrange the means of current control within reach of the hand without taking the fluoroscope from the eye.

By the simple yet efficient aid of the author's examining frame to retain the axis-path of the rays during all movements of the parts successively into the field the technic is reduced to mechanical accuracy. The sole remaining exercise of judgment relates to the regulation of the dosage of radiance. Practice the principles as taught in these lessons, and skill in diagnosis will rapidly develop along correct lines.

Intercurrent Radiography during Fluoroscopic Inspection.—If at any given point in the field the fluoroscope detects an apparent condition which you may desire to *radiograph* for finer definition simply tell the patient to sit still with the same field against the frame, unclamp the fluoroscope, slip in a plate, make the exposure, set aside the plate for later development, return the fluoroscope to the frame, and resume again the screen examination till it is completed. No other technic enables this to be done in so simple a manner, with perfect convenience to the operator, and no disturbance of the position of tube or patient.

Another Method.—An author who has made a very large number of X-ray examinations of the chest thus states the method he employs.

"During X-ray examination most of my patients lie on a narrow canvas stretcher, and the anode of the tube is placed three feet away when the thorax is examined, and usually under the point where the median line is crossed by a line joining the nipples. This position should be determined by plumb-lines. The median line is obtained by sighting from a permanent plumb-line that is fastened to the middle of the support upon which the head of the stretcher is placed to another fastened to the support at the foot in the same way. The other line is determined by putting a string eight feet long with a weight on each end across the chest from nipple to nipple at the level of the fourth rib. This line hangs down on each side of the patient, and the proper point is obtained as before by sighting from weight to weight. The patient should lie flat on his back, and care should be taken that one side of the body is not higher than the other. A small level may be placed across the sternum for this purpose.

"In all examinations of the heart it is important to have the light just right, so that the shadow of this organ may be brought out sharply and clearly. In young patients it is necessary to be careful not to have too much light, as then the border of the heart is not well defined. If the apparatus has a suitable means of adjusting the current to the tube the amount of light required is readily regulated."

Experts doing careful work on lines similar to the above will find the author's examining frame a great saving of trouble. Compare the two methods and note the simplicity of the frame.

Technic for Cardiac Exposures.—Ordinary directions state that the best picture of the heart may be taken with the plate upon the chest and the anode of the tube two inches to the left of the sixth dorsal vertebra. All directions for posture in radiography, which depend on securing a correct position of the tube *after* the part is placed on the table or plate, make difficulties for the operator and leave accuracy to guesswork. The aid of a mechanical device which adjusts the tube to a centre on which the part can then be accurately placed removes error and simplifies scientific technics. The author's examining frame does this. *Align the markers near the centre of the frame.* Focus the tube at twenty inches from the distal marker with

the frame suited to the cardiac level when the patient sits erect on a chair with the body sidewise in the frame. A single moment suffices to make this arrangement. It is as simple as sighting an opera-glass.

Next sit the patient on a chair with the chest in the frame. *Guide the body up to the anterior marker till the exact centre,* or apex, or base, of the heart—whichever you wish to be the centre of the radiograph—*engages in the angle of the marker.* It is done as simply and as quickly as you would place your finger tip on the patient's nipple. It secures the exact position instantly. Next, *slip off the markers* from the frame and slip in the photographic plate. *Make the exposure.* The plate can be backed with the brass cut-off and used with or without an intensifying screen, as desired. Another exposure can be made at once with the patient reversed, and without altering the exact focus *secured and maintained by the frame for as many exposures as may be wished.* The absolute superiority of this method over all others will be apparent on a single test.

The same posture without the plate is the correct position for examinations with the fluoroscope. Clamp the screen on the frame and the heart will be seen in the right place and alignment for the best view.

By this method one border or any desired point about the heart may be put in the path of vertical rays and examined without magnification. For method of tracing the heart outline on the skin or on record blank, see description of author's instrument in Chapter XI.

Radiograph of Chest with Patient Recumbent.—While pulmonary cases are for the most part radiographed in an erect posture (as will presently be taught), yet the recumbent position may be required in a given patient. To picture the general field of the upper portion of the thorax on both sides proceed as follows:

With the author's Position Finder centre the tube at thirty inches vertically over an 11×14 plate. Lay the plate on the base of the P. F. as taught. Remove all clothing to the belt and place the patient face down and flat on the table with the centre of the upper part of the thorax in the closest possible contact with the film at the centre of the plate.

Have patient *extend both arms full in front.* This forward extension of the arms removes most of the shadow of the scapulæ from over the lung-tissue and clears the field as nearly as possible. Direct the patient to maintain a full inspiration as nearly as possible during the exposure.

To picture a local field in the thorax in a similar manner centre a smaller plate at twenty inches. Strip the chest, examine, and mark on the skin the area of suspicion. Then lay the patient on the plate so that the centre of the essential diagnostic field will be on the centre of the film. Make the exposure as above.

To avoid blurring of definition from respiratory movements a ready method is to have the patient take a deep breath at the beginning of exposure, hold it as long as he can, and signal when he is compelled to breathe again. Then cut off the current while respiratory relief is secured. Then switch on the tube again with the chest inflated as before. Repeat till the exposure is complete. Or, the patient can be allowed to take a breath as quickly as possible without stopping the tube. In either case the object is to secure a sharp detail by a short exposure during which the chest muscles undergo the least possible change.

Movement of free respiratory actions or the slightest twist of the body, or the vibration of a tube in an unsteady support, will tend to blur the lines and dim the definition of the shadows. Use the utmost endeavor to secure fixation of the part while the rays are active and aim at a short exposure. Fat streams of rays from coarse twelve-inch coils and from thirty-inch Static machines, having from sixteen to twenty-four *revolving* plates, will secure a good negative in two minutes. Medium apparatus will require five minutes. With special film between two photographic screens chest pictures have been taken in one second; in a few seconds; with one screen in one minute; by different operators. Less efficient apparatus which requires ten minutes for the chest does not appeal to the expert, as the difficulty of producing clear outlines of parts so subject to variation of position increases beyond control with long exposures.

Several operators have suggested measures for minimizing these difficulties. One has constructed a switch moving synchronously with the respiratory muscles so that when the patient breathes the current is cut off. With the author's short-circuit stick the tube excited by a Static machine can be cut in and out to the same end. But the best road to fine skiagraphy of the chest is high-efficiency apparatus, rapid films, controlled respiration, and short exposures.

As shadows caused by structures outside the thoracic cavity must be distinguished from those produced by the internal organs the difference between muscular folds in very muscular persons, and the entire absence of them in cases of emaciation must not be overlooked. In this form of posture the axillary fold in front close to the plate often photographs very distinctly. Owing to the respiratory movements of the contents of the thorax the record upon the plate has

some unavoidable defects, and, if the *stereoscopic fluoroscope* is shortly brought to a simple, inexpensive, and convenient state, it is probable that few radiographs of the chest will be made. With such an instrument the operator could see the cavity *in situ*, could see the heart as a muscular body and not merely as a silhouette, and could note the contour of new growths and enlargements.

We will next study an arrangement for securing the *effect of fixation* of the respiratory muscles and organs so that they may be radiographed under as favorable conditions of rest as a joint. This is accomplished by an intermittent action of the tube so that the exposure is shut off while moving the lungs to get air, and only acts on the film at the one desired stage of respiration. This is for time-exposures which take more than a minute, or several minutes. The intermittent activity of the tube is made to coincide with the time the patient holds his breath by a rheotome device which we will now consider.

The Rheotome Method.—It was early discovered that there was a marked difference in the definition of a thoracic radiograph made during life, and after the death of the individual. In the latter, the sharp markings, the well-defined borders, the distinctness of the outlines of the heart, the diaphragm, and the extremities of the ribs, when radiographed in absolute rest, indicated how much the accuracy of an X-ray examination during life was impaired by the respiratory and cardiac movements. To place the examination of the thorax and abdomen upon an equal footing with other parts of the body, as nearly as possible, attempts have been made to *restrict the action of the rays to a single phase of temporary arrest of the function of all the organs*, save the heart. During *ex*piration the thorax is less suitable for radiography than at the maximum of *in*spiration, as the ribs are then closer together, the tissues more dense, and the reduction of air in the lungs opposes transparency. The heart also becomes overloaded and changes its shape under the increasing venous congestion, and dyspnœa.

During an exposure of the thorax the action of the rays may be limited *to the time of arrested movements of respiration*, either by alternately stopping and starting the current and the X-rays, or by alternately interposing and removing a sheet of metal in the path of the rays while the patient is allowed to breathe. But automatic apparatus has been devised by Cowl and is thus described:

"1. An easily movable, double-armed lever acts as a rheotome or automatic interrupter of the current, when so adjusted as to be acted upon by the movements of the body. By means of a platinum cona smaller plate at twenty inches. Strip the chest, examine, and mark on the skin the area of suspicion. Then lay the patient on the plate so that the centre of the essential diagnostic field will be on the centre of the film. Make the exposure as above.

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"1. An easily movable, double-armed lever acts as a rheotome or automatic interrupter of the current, when so adjusted as to be acted upon by the movements of the body. By means of a platinum contact at its other extremity the current is broken at the stage of respiratory movement corresponding to the adjustment made.

"2. A small magnetic electro-interrupter actuated by a separate weak current from cells and connected with the rheotome opens and closes the circuit of the main current which excites the coil and the usual interrupter, in a purely mechanical manner.

"To obtain a given radiograph at any point of inspiration or expiration the platinum plate at the contact is adjusted against the end of the lever which is supplied with two platinum points, so that closure of the current may be had by the movement of the lever either upward or downward. By means of a set screw the closure of the current is deferred to the desired stage of respiration. In order to apply the rheotome to the proper part of the body, it is arranged on a stand with an arm which permits movement in either a horizontal or vertical direction.

"In the use of the rheotome the patient is placed in the dorsal position on the photographic plate. The rheotome is adjusted so that the lighting up of the tube, and the sound of the spark of the interrupter of the coil-current occur simultaneously with the stroke of the hammer at the small interrupter on the core of the electro-magnet. The patient is now instructed to cease breathing after each sound of this last stroke of the interrupter of the rheotome. When he has practised this and grasps the idea, the main current is switched on. The patient is then 'almost unconsciously guided to control the respiratory movement by the rhythmical action of the luminosity of the tube and the sound of the interrupter.' The entire proceeding is automatic during the making of the picture. The rheotome, interrupter, accumulator, and stand, described, are made by Hirschmann of Berlin.

"The resulting pictures are very satisfactory as compared with those of the usual skiagraph of the normal thorax, which, at all the points affected by respiratory movement, show more or less broad cloudy margins which partly, or completely, obscure important details.

"Of two pictures taken under the same conditions, and the same exposure-time, the one taken during the maximum of *ex*piration will show a marked lack of distinctness, as compared with the one taken with the lungs expanded with air. Skiagraphs of this kind, however, do not excel ordinary pictures so much when they are taken of certain diseased conditions which fix or limit the movements of the affected organs, such as aneurisms, pleuritic adhesions, spondylitis, etc. The presence of sharp outlines at the edges of the heart and diaphragm on the ordinary skiagraph suggests a deviation from the normal state, and the determination of impaired mobility of the organs and the significance of the same, can best be obtained by means of two pictures taken by the rheotome method.

"Among the details to first attract attention in *ex*piratory as well as in the *in*spiratory picture is the great distinctness of the summit of the diaphragm and the rib, especially the anterior extremity of the latter; also the sharp borders of the aorta and the heart, besides the less distinct lines of the left ventricle, blurred by its independent movement which cannot be arrested during the exposure.

The outlines of the arch of the aorta to the left of the central shadow leave nothing to be desired as regards distinctness. The two auricles are, especially in the *in*spiratory picture, sharply distinguishable from the lung; the left auricle in both pictures also being strikingly enlarged, apparently being attached to the bulbus aortæ. The shadow of the descending aorta is partly covered by the transverse processes of the dorsal vertebræ, which, from the third downward, are located progressively lower beneath the respective ribs. The heart and aorta as a whole appear enlarged in the picture.

"As an explanation of the light area between the heart and the diaphragm (barely evident in the *ex*piratory picture but clearly marked in the *in*spiratory picture) it is assumed that the right ventricle located at the diaphragm, as well as the apex, is markedly distinct from the reflection of the pericardium attached to the midriff, as otherwise the aforesaid light area of the former would appear almost like that of the lung. The light space is produced by the separation of the diaphragm from the posterior portion of the heart at the maximum of inspiration and descent of the diaphragm.

"In regard to the reproduction of the external border of the left ventricle, rheotome-pictures of entirely normal and younger subjects show varying distinctness in outline. From a comparison of the results of the rheotome method, it is considered probable that the indistinct borders of the heart in the usual skiagraph are mainly caused by the movements of respiration rather than the action of the heart.

"The rheotome method is also recommended for radiographs of the abdomen, especially when it is essential to detect the presence of foreign bodies in tissues affected by the movements of respiration.

"In making an exposure with the rheotome device the lever is applied to a part of the abdominal or thoracic wall outside the path of the rays, so that it will not interfere with the picture." (Cowl.)

The next step forward aims at the effect of fixation in a different way. It calls for no ingenious mechanical device, but simply asks the patient to fix his respiratory muscles at a definite point for *one second*, while apparatus of high efficiency make an instantaneous or so-called "momentary" radiograph of the parts. It would seem that any careful student of this Instruction ought to be able to do the same thing himself after obtaining the necessary screens and quality of rapid films. The subject is most attractive.

Technics of Instantaneous Thoracic Radiography.—In the classical work of Von Ziemssen and Rieder in making thoracic radiographs with *momentary exposures during the arrest of a single deep inspiration*, the following technique is employed:

A coil with a twenty-inch spark rating.

An electrolytic interrupter.

X-ray films made by the Schleussner Company, Frankfort-on-the-Main, each sandwiched between two intensifying fluorescing screens, wrapped as one plate in light-proof paper.

A plate-holding frame adjustable to height on runners fixed to the wall. The patient standing on the foot of the device leans his thorax firmly against the vertical front of this frame with his chin resting on the upper edge. The tube is focussed to the centre of the film at twenty inches distance. After once focussing the tube and frame, either dorsal or frontal exposures may be made in the same manner. When ready, the patient takes a deep breath and *holds it*, the operator closes the electrical circuit for *one second*, and the film is then developed and treated as any other photographic plate.

As an improvement on the above add a plate of heavy sheet-brass as an opaque backing to the film, and steady and make closer the contact of the patient by a pair of side shoulder braces drawing moderately upon the subject. See Fig. 4, page 54.

Bearing in mind that the words "instantaneous" and "momentary" are employed here to mean an exposure of one full second, and not to signify exactly a "snap-shot," we will pass to the interesting study of this branch of X-ray work.

Studies in Thoracic Radiography by Professor H. Von Ziemssen and Professor H. Rieder. (Munich.)—No student of diagnosis can afford to miss the following contribution to the methods and researches of eminent men. Read it with care:

"Improvements in technique have conquered to a certain extent the difficulties of radiographing the inner organs of the body, and with this advance the practical value of the X-rays in internal medicine is assured. By their aid some of the most important physiological and clinical questions have been determined, especially since the method of "*momentary* exposure" has been employed. *Time*-exposures have their place and value, as has also the fluoroscope, and the combined methods greatly extend the range of examinations beyond previous accomplishments.

"At first the older methods of physical diagnosis seemed destined to hold their predominant place with no further aid from the X-rays than confirmation (without new knowledge) in diseases of the thoracic cavity, but the decisive diagnostic value of the rays themselves has become definitely established *by the introduction of improved mechanics and short exposures.*

"The clinical significance of radiography rose to a high plane when the success of *momentary* exposures, yielding pictures of the thoracic organs practically at *rest*, was demonstrated in 1899. With the increased sharpness and clear definition of the respiratory structures on

the plate many advantages were gained. Beyond its actual diagnostic value it possesses also the advantage of economy of time and permits the satisfactory exposure of persons dangerously ill or too weak to endure a long seance.

"The correct relation of the parts of the thorax is best shown by a radiograph taken by the 'momentary method' with the patient *standing*. The standing posture is generally preferable to recumbency, though both positions have their uses. In fluoroscope work the erect position of the patient is practically always the best.

"The fluoroscope gives the correct view of the position, size, and quality of the organs, and alone shows the phenomena of *movement*, as, the pulsation of a tumor, succussion of fluid in the pleural cavity or in the stomach, the action of the heart, the excursion of the diaphragm, the respiratory movements, etc. But if a means of measuring and comparing is required the radiograph is alone the stable, sharp, and definite diagnostic picture. It has become part and parcel of the patient's history in the clinical record of a case, and is often a document of high value.

"Experience also shows that a true picture of the internal organs affords a diagnosis in some cases sooner than other methods of examining, and that the diagnosis is made possible *only by the radiograph.* While the divergence of rays coming from a single point shadows the inner organs larger than they really are, we do not require the absolute size in diagnosis, but only the relative size and position of the parts. If we wish to ascertain the exact size of a particular part, as the heart, we direct the examination to that end in a different way.

"As the degree of enlargement is in ratio to the nearness of the tube to the part, or the distance of the part from the film, we should make all comparative examinations at different periods at a standard distance of the tube and with the part as close to the plate as possible. Our standard distance is twenty inches betweeen the anode and the film. Only when this condition is fulfilled can pictures be compared with each other.

"In diagnosing the growth of the heart or of an aneurism or tumor, etc., these conditions are of serious consequence. The plate must in each case have the same relation to the wall of the thorax. Also there must be the same position of the diaphragm and the other structures of the thorax as represented by a given phase of respiration, as pictures taken without exact observation of these data lose their measure of value.

"Either deepest *in*spiration or deepest *ex*piration is exceedingly important in radiography of the thorax. *We generally choose the arrest at deep inspiration.* Have the patient practice precision in attaining and holding this position before the exposure. The beauty and sharpness of the outlines gain greatly by this position of the parts *with the ribs spread, the ribs and scapulæ elevated by extending the arms at right angles to the body, the lungs rendered most transparent with air, and the muscles and diaphragm resting.*

"The apex of the heart at the same time rises in a triangular shape and is seen very sharply on the flat part of the left diaphragmatic arch. Alterations in the free mobility of the diaphragm, partial fixation from pleural adhesions, small exudations, and other abnormalities can then be best defined.

"We choose generally the position of deep inspiration with the patient standing erect for our instantaneous pictures of the thorax.

"The branching of the bronchial tubes, thickening of the lungs, tubercle, etc., cavities, etc., are seen sharpest by this 'momentary' method. These are its great advantages, and when 'time' exposures are not indicated for diagnostic reasons *it is the method of choice of those who practise it.*

"On the other hand time-exposures *without* intensifying screen are preferable on denser parts of the body and in diseases of the bones, as caries, arthritis, tubercular disease, etc., when definition of minutiæ is required and the parts are normally at rest.

"Among the interesting observations of thorax pictures taken by the momentary method is the fact of the unequal heights of the two arches of the diaphragm. The popular idea that the diaphragm had two equal halves which moved alike in respiration is shown to be false. In both sexes and in all ages the right arch of the diaphragm usually rises higher than the left in health. There is often only a very small difference, but it is nearly always present in some degree and is visible in different respiratory phases, an interesting fact developed by exact radiography. The deep plane of the left arch falls more decidedly lower in cases of great hypertrophy of the heart. Hypertrophy of the left heart shows the apex beat in the sixth intercostal space. The fluoroscopic 'size' of the heart apart from age, sex, and size of the body, depends on the respiratory phase, and *to secure the best view place the patient in the position of deep inspiration.*

"Then the examiner can see, with a well-defining tube, changes in the lungs, pleura, and the diaphragm, and organs of the mediastinum, which are especially difficult to make out by auscultation and percussion. The retraction of the borders of the lungs from over the heart exposing its body plainest, the one-sided slope of the diaphragm caused by adhesion, tumors of the mediastinum, commencing pulmonary deposits, etc., can then best be made out.

"For general diagnostic information and analysis of *functional movements* the fluoroscope holds first place. But when detailed study of *pathological change* is required the radiograph is essential. If the first exposure fails to satisfy, make another.

"The difference between an acquired and congenital dextro-cardia can be seen at first sight with the fluoroscope. The more exact knowledge, difficult to otherwise diagnosticate, of the combination of cardiac hypertrophy with moderate pericardial and pleuritic exudation, is only gained with the radiograph; especially the question which arises so often as to whether the enlargement determined by percussion has its cause in hypertrophy only or is combined with pericardial exudation.

"*Pericardial effusions radiograph best when the patient lies in the abdominal position with the chest on the plate,* as then that part of the pericardium which lies against the front wall of the thorax is filled with the fluid.

"Especially instructive are pictures of the pneumo-thorax. By slight shaking of the body the wave-like movement of the fluid can be seen with the fluoroscope, rising and falling against the side walls.

"The kind and degree of displacement of the neighboring organs, the compression of the lung, the distension of old pleural adhesion, are easily demonstrated by the radiograph. All these pictures of marginal limits, of pleural adhesion, of transudations of the pleura, the degree of displacement, the irregularity of the borders of exudation at the period of resorption—the definite adhesions, are instructive for the student as well as for the physician.

"We are now much more careful with the fluoroscopic diagnosis of *aneurism* so long as it is of small extent, and belief in the decisive importance of pulsations as compared with mediastinal tumors is shaken.

"On the other hand, *the small half-globular elevation often seen in the left mediastinal space is not to be mistaken for aortic aneurism.* This prominence is probably caused *by the crooked position of the normal arch of the aorta* where it crosses the vertebræ. Post-mortems have shown that no aneurism existed in cases when this appearance has been noted, and further investigations will throw more light on the subject. If the radiograph and fluoroscopic examinations go hand in hand with other findings in the general examination for aneurism (when it is well developed) the diagnosis has no difficulty.

"The details of size, shape, and position of the aneurism against the mediastinum and heart, the displacement and flattening of the latter, would be shown by the radiograph, which should *always be made both dorsal and ventral.* The differentiation of a sub-sternal struma from an aneurism is easily shown by a radiograph on account of the irregular film structure of its lobes and of its chalky deposits, while aneurism has a regular diffuse shadow.

"The radiograph can be very valuable if there is a question of a differential diagnosis of bone and joint diseases, fungus, arthropathia tabica, arthritis deformans, hysterical joint neurosis, rachitis, osteomalacia, etc. The radiograph can give the diagnosis at once.

"In diseases of the lungs both the fluoroscope and the radiograph give valuable information. The parts of the lungs which are covered by the heart cannot be seen. This dark part of the lung belongs mostly to the left, though partly to the right, lung. *The apices of the lungs, as many negatives prove, are best seen in a vertical position of the patient.* We do not find that the clavicles are so great an obstacle as Levy-Dorn described. The fluoroscope shows both apices best if a *pliable screen* is used.

"To get a clear view the fluoroscope must be placed behind both supra-spinal regions, with a *slight backward bending* of the patient.

For the best front view of the apices a screen of triangular shape is used to show clearly the supra- and infra-clavicular regions.

"Abdominal diagnoses have not gained so much from the X-rays as the thorax, nevertheless valuable data are ascertained, and, as technic makes progress, results will improve. The size, shape, and position of the stomach, and the cardiac end of the œsophagus, can be shown by the aid of bismuth. The spleen and kidneys, *in persons with thin and delicate soft parts*, can be radiographed. The diagnosis of diaphragmatic hernia has been made after many fluoroscopic and radiographed experiments.

"By the injection of bismuth emulsion into the rectum the size and shape of the canal can be seen. Injections of gas distend the walls, cause increased transparency, and define a stricture."

CHAPTER XVI

DIAGNOSTIC OBSERVATIONS

The X-Ray and Coxalgia. Spina Bifida. The Brain. Arthritis. Thoracic Surgery. Solid Tumors. Subphrenic Abscess. Arterial Sclerosis. Carcinoma of the Œsophagus. Spoon in Œsophagus. Deviations of the Spine. Pott's Disease. Callus. Tarsus. Larynx. X-Ray Examinations of Children.

Among the many miscellaneous observations that have been made by different workers in fields of X-ray diagnosis we may well study a few which have been selected somewhat out of regular routine. A simple resumé of these phases of investigation will suggest hints for use when needed. It is not to be expected that absolutely every variation of X-ray showings can be presented in a formal survey, for to do so would fill a shelf with books; but examples such as are here cited are instructive and sufficient.

The X-Ray and Coxalgia.—In presenting a paper on Coxalgia, Coover remarks that, until the introduction of the X-ray, the early structural change undergone by the bones involved was largely a matter of surmise, although post-mortem examinations revealed a degree of absorption, necrosis, and local thickening, pelvic distortion, and inflammation of periosteal, ligamentous, and muscular tissues. Omitting the general considerations of his paper his note on the radiograph presented by him was as follows:

"On May 2, 1900, an X-ray photograph of the pelvis of the boy was taken at the Harrisburg City Hospital. Observe the great change in the left pelvic bones. The head of the femur is still in its socket, although the rim of the acetabulum is being absorbed and a degree of effusion exists. Careful measurements of the original photograph show considerable inequality between the two sides as regards the pelvic rim, the ischii and obturator forameni, and the trochanters major. The radiograph was taken with the face of patient nearest the photographic dry plate. A second one, taken six months after treatment begun, showed no effusion and some degree of improvement in the contour of the bony tissues, particularly the trochanter major and the acetabulum."

Josseraud has fully demonstrated the value of this method of diagnosis in the determination of the exact condition present in cases of coxalgia, and the beneficial influence which it has had upon the treatment in these cases. He has shown that the skiagraph will demonstrate the presence of osseous lesions and detect sequestra, making it possible to determine the exact condition of the bone and the situation of the lesion, so that if it is simply cartilaginous, or in the incipient stage, it can be treated by extension and rest, while the presence of any grave osseous lesion makes it possible to operate and remove the sequestrum or diseased area of bone before symptoms are present that would indicate it under other circumstances.

Spina Bifida.—The radiograph now shows with absolute distinctness whether or not there is an opening in the spinal column. It shows also the presence or absence of the nerve substance, and sometimes even its expansion in the sac. In those rare cases in which the presence of a lipoma or fibromyoma is in question the radiograph gives the needed information.

The Brain.—Regnier reported in 1900 his radiographic researches on the topographical relations of the brain, the frontal and maxillary sinuses, and the venous sinuses of the dura mater to the walls of the skull. His researches were undertaken to ascertain the relation of the brain to the skull, and to determine certain points in the anatomy of the skull and face. It was found possible to see the brain through the skull *in prepared subjects*, and thus to study the relation between the cerebral convolutions and the walls of the skull. Injections of liquefied substances which would become solid or which held metallic substances in suspension were made into the venous sinuses in order to study them.

The bony cavities, the walls, and the sinuses were best studied in dry preparations. The convolutions were best visible after the removal of the pia mater. The time of exposure of the radiographs made varied from ten to forty minutes. To anatomists wishing to repeat his experiments he advises that in selecting material for this work young subjects should be chosen, and arterial injections containing hardening materials should be repeatedly made. After about two weeks, the brain may be carefully removed from the skull, freed from its pia mater, and replaced.

In working out a diagnosis in a doubtful and difficult case, there is a lesson for all operators contained in the following report:

"We should never be satisfied with one radiograph of a case, but should make radiographs from different positions and compare also the picture of the injured part with the normal one. J. B., age thirty-nine years, sunstroke six years ago. Since that time a complaint of dull persistent headache on the left side of the head; altered disposition; was irritable, had vertigo, dyspepsia, vomiting, soon followed by slight palsies, but no convulsions. Lately retention of urine and symptoms more obscure. Muscles and mental state were unimpaired. Patient brought to me for X-ray examination.

"Twelve-inch spark coil was used, with Wehnelt interrupter. Tube ten inches from surface of head; plate behind the head; *photographic screen of tungstate of calcium placed over the dry plate to shorten the exposure.* Patient in elevated position with head low down. Exposure-time five seconds. With the parts of the head not examined covered with tin-foil, and those which were exposed shaved and oiled, I made six radiographs. The first one revealed nothing special, but the last one showed plainly a large epidural clot under the parietal bone at the sagittal suture on the left. The clot, amounting to four ounces, was removed, and recovery followed in three weeks without any complication." (JICINSKY.)

Few surgeons can point to a more satisfactory result of painstaking persistence in an X-ray examination than this.

Arthritis.—Radiographs distinctly show the absence or presence of enlargement of the articular ends of the bone in arthritis. The difference in the constitution of the joints in rheumatism, arthritis deformans, and gout is clearly shown. Cloudiness in the joints between the bones may be noted. In far-advanced cases of arthritis deformans the joints lose the clear transparent appearance and become dark in color.

The cartilages of joints are normally very permeable to X-rays, but if they atrophy on account of arthritic processes the radiograph often presents the appearance of ankylosis. The interspace normally found between the joint disappears, but the differentiation between diseased cartilage and ankylosis is easily made by the presence or absence of motion.

In Thoracic Surgery the X-rays have demonstrated that after subperiosteal resection of a rib, the exsected portion is always more or less re-formed. The extent of a thoracic pus-cavity can be shown by filling it with iodoform-glycerine. Subnitrate of bismuth gives a more marked shadow, but as it interferes with the treatment its use is not recommended for this particular purpose.

Solid Tumors, such as osteomas, osteo-chondromas, osteo-sarcomas, enchondromas, and fibromas, are successfully radiographed. In a case of aneurism of the thigh, with entire absence of pulsation, a surgeon was unable to identify the character of the tumor by the X-rays, but he excluded several possibilities for which the hard immovable growth could have been mistaken; viz.: osteoma, osteo-chondroma, and osteosarcoma. The aneurism gave no shadow, being covered by thick muscles, while tumors would have given a shadow. The structure and outline of the bone also show distinctly in aneurism.

Sub-Phrenic Abscess, the diagnosis of which was formerly so difficult, has become simple; the space between the diaphragm and the lower boundary line of the abscess showing distinctly. If situated between the diaphragm and the liver, the image is particularly distinct.

Sclerosis of the walls of the large arteries may be shown in nearly every part of the body by means of the X-rays, and the presence or the absence of deep arterio-sclerosis determined by positive or negative evidence. Aneurism of the carotid artery, the subclavian, the anonymate, and the abdominal aorta, have also been identified with the X-rays.

Carcinoma of the Œsophagus.—In attempting to make a differential diagnosis with the aid of X-rays between aortic-aneurism and intra-throracic tumor, Gebauer had the following experience. A pulsating tumor was seen and the pulsation was thought to be distinctly expansile. The diagnosis was made of an aortic aneurism. There was dulness under the sternum. Oliver's symptom was present, there was a systolic murmur, and the left vocal cord was paralyzed. There was, however, a marked difficulty in swallowing that was considered unusual for aneurism. The post-mortem showed a round pulsating carcinoma of the œsophagus, with a communicating abscess cavity, the mass being situated nine centimetres below the inter-arytenoid folds. The diverticulum formed in the wall of the œsophagus, had become adherent to the posterior wall of the aorta. This evidently explained the dysphagia and the expansile pulsation.

Spoon in Œsophagus.—In the case of a man suffering from melancholia Stembo made an X-ray examination and found a spoon in the œsophagus. It was twenty and a half centimetres long, four and one-tenth cm. wide, and the bowl was toward the stomach.

Diagnosis of Deviations of the Spine.—1. *Pott's disease.*—Redan and Loran report that a number of their radiographs clearly display vertebral tuberculous foci at different periods of development. Initial tuberculous lesions were revealed by radiographs of the vertebræ. In several cases the existence of the disease was thus discovered and treatment begun when the objective and subjective symptoms were too obscure for diagnosis. The radiograph also discloses, besides the number of vertebræ affected, the extent and depth of the tuberculous lesions, as well as the alterations in the neighboring tissues and organs. At an advanced stage of Pott's disease the negative indicates the extent of the lesions, the importance of the loss of substance, the existence of sequestrations and of tuberculous cavities, and the degree and cause of rachitic curvatures. Cold abscesses, particularly those treated by iodoform and oil, make a shadow on the plate. Negatives made at different periods will indicate the advance or decline of the tuberculosis process.

2. *Scoliosis.*—In scoliosis the X-rays disclose information which otherwise is usually only learned at the autopsy. One can see very clearly upon the negative the dorsal and lateral aspects, the various deformities of the body, pedicle, and arch of the vertebræ. Upon a number of plates taken by Redan may be noticed the bony union of several vertebræ and the existence of osseous products at the periphery, which teach us the stage of the case and the degree of rachitic rigidity, and consequently fix the prognosis and curability of old cases. It is demonstrated that the osseous tissue of the concave side is more dense, and the medullary spaces more close than on the convex side. Further, contrary to the usual opinion of former times, the osseous structure of the concave side, far from being atrophied, is the seat of a hypernutrition and of an osteo-genesis much more marked than upon the convexed side.

Callus.—The formation of callus may be studied by means of the X-rays. The quality of the callus and the development of density and opacity to the rays will vary with the age of the subject. In all X-ray examinations the trained observer must allow for age somewhat as the medical prescriber varies the dosage of certain drugs for adults, children, and infants. The difference in the proportion of animal matter (so readily transparent to X-rays) in the bone at different periods of life must be constantly taken into account in the interpretation of shadows. In some observations on callus, reported by a surgeon who does not state the age of the subject, there appeared after twelve days a slight shaded area at the ends of the bones which gradually became darker. In oblique fractures of the tibia the callus remained invisible for a longer time even after consolidation appeared to be complete. With a little care and some experimental work with bones and joints of young animals which may be obtained from the butcher's, and with some study of the shadows of cartilage between the joints of children of different ages, the interpretation of callus and a uniting fracture will be made with confidence. Early reports that the X-rays would show a fracture where none existed were undoubtedly based upon the untrained observations of men who had made no study of the shadows of cartilage and slowly consolidating callus. Early errors also arose from incorrect placing of the tube and the consequent passage of the rays in such a direction or slant that they failed to traverse the line of fracture. Obviously, if you do not look at an object you will not see it, and if X-rays do not "look at" the fracture they will not see it so as to report its existence.

Tarsus.—The chronic tumor-like swelling in the foot which interferes greatly with the walking powers of the soldier, and which arises from slight traumatisms, such as the sudden striking of the foot by the rifle butt, etc., has been looked upon as due to an inflammatory condition of the soft parts, as the tendons, joints, etc. The X-rays have shown that it is really caused by a fracture of one of the metatarsal bones, so that instead of applying massage and gymnastics, the foot is put up in plaster, and rapidly gets well with rest.

Larynx.—According to Freund the physiology of vocalization can be intimately studied by means of the X-rays. The alterations of the palate during the pronunciation of vowels, consonants, and various sounds in different tones have been watched with the fluoroscope.

X-Ray Examinations of Children.—A number of writers have emphasized the usefulness of the X-ray with children. With tissues easily penetrated, and small enough to bring very near the screen, a moderate radiance often enables the fluoroscope to reveal more in proportion than with adults. With non-noisy X-ray apparatus such as many operators employ, children are not alarmed, and may be examined without the removal of clothing, either recumbent on a canvas stretcher, or held by a nurse. Infants, indeed, sometimes go to sleep on the stretcher, and may be examined with the fluoroscope, or a radiograph taken, without disturbing them.

The thorax, abdomen, and head of children are all more accessible to this mode of examination than those of adults, on account of their diminished density and size. But the dosage of X-radiance must be reduced to the needs of the tissues. If rays are used of such penetration that the *borders* of the heart are rendered transparent, the shadow of the body of the heart will appear to be singularly *small*.

In some cases of pneumonia, especially the early stages, it is claimed that the presence of pneumonic areas may be determined by an X-ray examination when there are no physical signs. A writer cites a case—"A child of six years with high temperature, a leucocytosis (25,000), pain and stiffness in the back of the head and neck, the neck so rigid it could not be flexed. There was no history, and no physical signs were found in the chest after a careful examination by three other physicians who agreed on a diagnosis of cerebrospinal meningitis. In order to obtain further information if possible, an X-ray examination was made, and, finding a dark area over one lobe and a shortened excursion of the diaphragm on that side, the diagnosis of pneumonia was made without hesitation. This diagnosis was confirmed by a marked crisis and rapid clearing of the lung, as noted by later X-ray examinations. At no time during the course of disease could signs of consolidation be obtained by auscultation and percussion. In young patients with symptoms which suggest tubercular meningitis, it may be desirable to make a careful X-ray examination of the lungs, with a view to determining whether or not tuberculous foci exist there.

In pleurisy with effusion, or empyema, the X-rays may assist much in the diagnosis. Any condition of the lung which makes this organ less penetrable to the rays than normal, or limits the excursion of the diaphragm, may be easily observed. All the changes of the heart which in children are not readily detected by ordinary methods, are very definitely disclosed to the eye with the fluoroscope, and suitably adjusted X-rays.

The position and size of the spleen and liver are more readily observed in children than in adults. This is also true of the size and position of the kidneys, particularly the left kidney. By feeding the child bread and milk with subnitrate of bismuth, the size of the stomach may be determined, and the changes in size and shape after a meal may be followed. The changes in the size and shape of the stomach of a child during the process of digestion have thus been watched by Cannon and Williams. The advantages which young patients offer to this method of examination are sufficient to suggest that it be much more extensively employed by the profession.

CHAPTER XVII

THE ART OF READING X-RAY SHADOWS

Lessons in Interpretation. The Study of Shadow-Values. Definition and Contrast. Accessory Shadows as Aids to Diagnosis. How to Study Negatives and Prints. Directions for Beginners. X-Ray Atlases. The X-Ray Picture not a Silhouette.

The beginner will realize that *experience* is necessary in X-ray work; just as it is essential to the satisfactory handling of surgical tools, or the stethoscope, or the treatment of pelvic and rectal diseases, or the examination, diagnosis, and treatment of lesions of the eye. It is so simple a matter for any one to make a radiograph of a hand on the first attempt, that the experience required for valuable *diagnostic* radiography may be under-estimated. Tons of negatives and prints have been made as mere exhibits of X-ray shadows, without the slightest regard to the requirements of *diagnosis*. To raise the standard of his work the student should begin with the idea that every picture he makes must be made with an *object*—made to *accomplish something*—and not to simply add meaningless proof to the established fact that X-rays can impress an image on a film.

Not only take each picture in your early work with a definite determination to attain a definite result, but keep, compare, and study every failure and success with the plates side by side, and a record of the conditions under which they were taken. Not only compare the images on the plates, but keep in mind a mental picture of the part radiographed, and consider why in one case certain markings appear on the plate and in other pictures of similar parts quite different markings are obtained. The most rapid illuminator of the mind is a *quantity of experience, well-digested.*

Collect a considerable number of radiographs and study them, with a view to the basis of correct interpretation. In a month the man who does this will learn more and will possess a better critical judgment than others who may take a far larger number of pictures but who only glance casually at the " bones."

The language of an X-ray picture is intelligible only to those

who speak it themselves. The knowledge of the language is attained by practice and experience, on the same principle that any other art is mastered. Behind the picture must be the trained understanding of what it *ought to represent,* and, therefore, a radiograph of the chest, eloquent to the pulmonary specialist, may be meaningless to the orthopædic surgeon; a picture instructive to the surgeon may mean little to a dentist, and neither the physician nor surgeon could well interpret the most beautiful work of the dental skiagrapher. The wonderfully scientific and remarkable ophthalmic work of a London surgeon, who has localized upward of 300 foreign particles in the eye during the past three years, would be as unhandy and as obscure in exact meaning to the general practitioner as would be the ophthalmoscope in the hands of a chiropodist. Therefore, each worker should grasp the idea that he must study radiography from the stand-point of what he himself *needs to show by it* in the class of cases which make up his particular practice. No one person will have time to become expert in every branch of electrical and X-ray technique and it suffices to attain reasonable skill *within the scope of your own work.*

These suggestions should direct the student wisely in concentrating his experience upon those uses of X-rays which will assist him with his own patients. After the foundation of skill is laid practice will naturally broaden the field of work. It remains, however, to say that while a correctly taken radiograph will be a truthful picture, yet it is not expected to tell the whole truth unaided, and when it has told all the truth it can we must be satisfied and supplement its story with other clinical evidence.

Various writers state that in order to lessen the chances of wrongly interpreting the appearances shown by a radiograph the operator should mark the point on the plate where a perpendicular drawn from the focus meets the film. With the author's " position finder " and circular landmark the diagnostic field on both plate and subject are automatically marked out. This delimitation of the diagnostic field centred in the axis of the rays is of primary importance. The radiograph has rendered great service in the diagnosis of fractures by revealing the number of fragments, their form, their position, their displacement in different directions, the location of splinters, etc.; but a special point for interpretation is the apparent overlapping of the ends of bones when this appearance occurs in the negative.

If there is an actual overlapping of one fragment upon the other and the exposure is made with the part at right angles to the central axis of the rays, the amount of overlapping in the picture will almost exactly correspond to the amount of shortening in the limb. If, however, there is no shortening and no *actual* overlapping, a right-angle view cannot produce the appearance of it in the picture, but it can be caused by posing of the tube and patient out of a right angle. If the rays pass through the upper fragment at an oblique angle instead of in a perpendicular line, they will project the shadow of the bone which is farthest from the plate beyond the shadow of the nearer fragment. This effect can be well studied by placing a small pair of scissors upon the back of the hand with the palm on the fluoroscope, and noting the "overlapping" caused by different departures from the central axis of the rays. The revelations of a moment of visual inspection will suffice to demonstrate this feature of the interpretation.

It is commonly said that for the purpose of gaining an accurate knowledge of the nature of a fracture it is necessary to take radiographs of it "at different angles," usually a front and side view. Those who write thus usually go on to say that "it is possible for a fracture to be unrecognized, even though it exists," and a strong point is made of this fact in references to medico-legal evidence. A few moments' study of a long bone in which you have made a half-dozen saw-cuts of various depths and directions will suffice to show that the vital point in the interpretation is not the taking of radiographs at different angles simply, but the centering of the break in the axis of the rays so that *the line of broken opacity will be traversed by the rays which act upon the film.* Put your eye at the side of a key-hole and attempt to see through the hole in the door. Unless the light from the other side of the door *reaches the eye in a straight line through the hole* your inspection will be negative. The study of radiographs with this principle in mind will interpret the shadows correctly if they were correctly made by a proper exposure, and if incorrectly made will interpret to a great extent the faulty position of the tube and the reasons for failure.

Crude and unskilled developing and treatment of the plate after the exposure is made will also interpret themselves to the trained eye of the observer who sufficiently studies the photographic technics of X-ray work.

On the other hand, it is often claimed that "the fluoroscope has not enabled the surgeon to detect a fracture." Some experimental study of fluoroscopy and its artistic refinements will easily interpret many failures. The secret of correct interpretation of a fracture with the fluoroscope is *clear definition* and correct alignment. Make a series of tests with any body of mixed densities and see how many variations of position, distance, and dosage of radiance will give nega-

tive results, and how exactly localized *is the narrow field of examination in which the view of the shadows will be correct.*

A screen which has deteriorated from lack of care, age, abuse, or was never of good quality, will not give clear definition. The finest fluoroscope procurable is the only one which should be used. The ordinary fluoroscopic examination as commonly made is so crude and unscientific in technique that it is superfluous to describe at length its long list of faults.

Briefly, it may be said that *correct interpretation with the fluoroscope requires the central fixation of the field, a right-angled relation of the plane of the screen to the axis of the rays, the closest possible approach of the part to the surface of the screen, and the regulation of the distance from the tube and the dosage of radiance to produce the degree of shadow-contrasts and accurate definition which is essential to the interpretation.* Follow this rule, and abandon haphazard manœuvrings with the fluoroscope at all sorts of distances and in all sorts of aimless directions, and accurate interpretation will follow, within the limitations of the instrument, *if the tube is efficient.*

The need of care in the interpretation of *marks on X-ray plates* is exemplified by the incident reported by Curtis to the New York Surgical Society. A child had swallowed a hat-pin two inches long with a glass head. The fluoroscope failed to detect it. An X-ray picture was made and apparently showed a thin dark body like the shaft of a pin in the œsophagus. This mark was afterward proved to be a defect in the gelatine coating of the plate—not a mere scratch on the surface which could have easily been recognized. The recovery of the pin in the stool proved that it was not lodged, and it may also be said that a more competent exposure with a fine tube would have made such a defect in the plate of little liability to deceive. Probably nine-tenths of the literature on X-ray fallacies should be understood as really but the growing period of skill before experience has taught the operator that a straight line will always be a straight line if he draws it straight. If drawn crookedly the fault is the operator's and not the line's. X-rays are straight lines, and nothing deflects them from a rectilinear path. In cases like the above "distortion" is not in question, but the error certainly was not of the rays.

The following item will interest many who seek explanations for some of their apparent failures in special cases:

"A blood-clot will often obscure a foreign body. In a case brought to me for a radiograph of the hand to locate a needle I did not remove the bandage. The doctor assured me that there were no pins in the bandage, but said that he had made several incisions where the needle was supposed to be. I made an exposure and found no needle, but found light, irregular lines which examination proved to conform to the incisions which were filled with clotted blood. Another exposure was made, and the developed negative showed the broken needle but no outlines of the clots. The needle was under the clot of one of the incisions and appeared on the plate after the clot was washed away.

"In another case while trying to locate a piece of steel in the eye I made an exposure with the plate on the side of the head and the tube opposite, but in the negative could not get the outline of the cavity of the orbit as is usual. I concluded that the reason for failure was a clot of blood. This was proved to be correct, as the eye was afterward removed and found filled with clot. The piece of steel was in the clot."

The Study of Shadow-Values.—The foundation training of the eye for the clinical interpretation of skiagraphs lies in the study of *shadow-values.* These values are relative and comparative. No part of the picture can be studied out of its environment. An isolated shadow may have no value. Nor do given densities of tissue create given degrees of opacity which can be valued out of their place. But just as we must know parts of speech before sentences can be construed, so we can study separate shadows to prepare the eye to read the entire picture.

Get together a dozen small blocks of wood, soft and hard, and varying in thickness from one-fourth inch to two inches; a few books of various thicknesses; some small and larger glass and wooden bottles; several sheets of tin-foil; a foot of sheet-lead; and at the butchers procure assorted bones and joints of various sizes, both of lamb, veal, beef, and fowl. Let some of them have the meat still on them. Add a variety of metallic trinkets and begin with the fluoroscope.

Take a single article at a time and observe its shadow—outline, margin, density, and definition—as these appear at different distances from the tube, and at different degrees of removal from close contact with the fluorescent screen.

Then partly *overlap* two articles and study the relative density of the single and double shadow. Increase and decrease in turn the penetration of the rays and note the effects of altering the position of the screen and the angle of the articles examined.

Twist and turn the bones and test the alteration of shadow caused by movements of the joints and different relations of the joints.

Observe metallic objects held on the proximal, and next, on the distal side of bones of different thicknesses. Also between two bones.

Also buried in soft parts. Note that the space between the metal and the screen affects the shadow in a typical way which tells its own story to the expert in his subsequent examinations in practice. Study all the possible effects with solid bodies, and then repeat them with liquids.

Partly fill the bottles with water. Study the shadow of different quantities of this fluid. Shake the bottle and note the visible waves. Wooden bottles will give about the same shadow as the same thickness of flesh, and they afford an excellent means of study. After noting the effects of water compare the shadows of blood, sputum, pus, etc. Particularly study how to manage the activity of the tube and your distance from the anode to secure the best shadow of such translucent substances as these last, especially when they are in small quantities. Much of the value of an X-ray examination of the chest will be lost unless the operator first acquires the art of securing the shadow that he wants to observe.

During these studies aim constantly at the maximum *definition* of each shadow before passing to the next. Study to develop the greatest contrast between two overlapping shadows, and do not consider the technic correct till it is adjusted so as to bring out all possible details. The importance of this early practice will appear later on.

In making these tests also note the effect on your powers of observation by a continuous hour's work in a completely darkened room. Hold the flame of an alcohol-lamp in the sunlight and you can see little of it; look at it in the dark and it shows fine contrast. That is the way with X-ray shadows. With an open screen they cannot be seen at all in daylight; with the closed fluoroscope they can be seen in a lighted room, but till the eye has had time to alter its sensitive mechanism the dimmest shadows will be lost. This may make no difference in a gross examination, but in fine work, such as the early diagnosis of tubercle, attention to this detail is necessary.

Develop these studies till practice gives confidence. Then practice similar observations on selected persons in ordinary health but of different ages and different muscular and bony mass. Learn the important fact that *each examination of a patient must individualize the technic and the findings,* for no two cases present exactly the same densities and relations to the screen or plate. Study of normal appearances is essential, just as study of normal histology is essential to the pathologist.

Then repeat some of these same tests with small plates. Develop the shadows that different substances can be made to cast on the negative by different "doses" of rays. Aim at contrast and clear definition. Learn how to avoid losing a faint shadow by over-exposure. Radiograph small masses of blood, serous and purulent sputum, sections of liver, heart, and other soft parts, fluids and various salts, metals, bones, etc. Make the pictures at different distances from the tube, and also study the effects of oblique variations from the central *axis* of the rays. A few dozen small plates used in this way will instruct much.

Definition and Contrast.—When the beginner has crossed the Rubicon, when he reaches the point of securing an apparent abundance of light, and sees no further obstacle in the way of his doing all that he reads has been done with the X-rays, the most important improvement needed in his work will be found to be the careful study of *definition.* The novice at first overlooks this factor in his joy at obtaining a bright radiance, but the expert looks more to definition than to mere quantity of light. The study is full of interest.

Light up a tube. Dash into it pell-mell a spluttering excess of exciting current and then look at a heart through the fluoroscope. The hazy shadow merely flickering on the screen gives you no idea of the true heart and its size or outline. There is no diagnostic value to the examination. But now with more care adjust the current to the indications of the tube, control the dosage to suit the capacity of the vacuum, smooth the interrupter to a sharp and even action, and then look at the same heart. In a favorable subject the heart can be seen as clearly outlined as a pear in front of the eye.

Look at the last joint of a single finger. Is it blurred or clear and sharp? Scan the bones of the wrist. Do the shadows merge and poorly define the articulations? Study at what position of the part, what distance from the tube, and what regulation of the current the separations are best seen. Look where the bones of the forearm, the muscles, the two shirts, cuffs, and coat-sleeve, make successive layers on the screen. If they appear in graded shadows, each distinct and plain, the proper definition of both tube and fluoroscope is demonstrated. But if not, then:

1. The fluoroscope, if an old one or not known to be up to standard, may be at fault, and its screen may be tested by comparison with another with the author's gauge.

2. The part under examination may not be in proper relation to the axis of the rays and at the best distance. Shift the part till the best effect is arrived at.

3. The quality and dosage of the current may not be regulated as needed. Try other adjustments till the tube works best.

4. *The focus of the tube may be defective.* This was common in 1896, and a simple test could often be made to show "astigmatism," and even at this date only the best tubes may be deemed well focussed. But too great a bombardment for the capacity of a tube will blur the focus and fog the definition. (Seventy-five per cent. of all the tubes entered for the gold-medal prize in 1901 failed in definition.)

5. If all these conditions are correct, and if a radiograph be taken and found lacking in sharp lines, the fault may be due to vibration of the tube if the holder or an unstable floor is stirred by heavy walking during the exposure. Movement of the patient is the cause of a blurred picture in many cases.

Having begun the study of *definition* compare your own prints with the best examples of others that you can procure till your judgment is trained. To comprehend much of what is meant by "poor definition" compare an ordinary *half-tone* of an X-ray picture with a really fine *print* of a similar picture. In the half-tone the details are not clearly defined, and, although a bullet or gross fracture shows its presence unmistakably in the reproduction, yet in many an able article published in the medical journals of the last four years and illustrated with half-tones authors have referred to so much that the reader could not trace in the pictures that it has been hard for a novice to acquit X-ray writers of imaginative exaggerations. Therefore, compare originals. Train the eye to recognize a lack of detail and learn to account for its cause in the technic. More practical knowledge can thus be gained in a few weeks of intelligent comparisons than unobserving operators will acquire in years.

Closely related in character and importance to sharp definition in an X-ray picture is marked *contrast* between the shadows of differing densities and different planes. First study by comparison of plates and prints the full significance of the word "contrast" in shadows, and then mentally digest the principle of procuring them. It is obvious that an excessively long over-exposure will reduce the contrasts by obliterating the lesser densities, while too short an exposure for a given purpose will not properly develop them. Therefore, after every other part of the technic has been mastered, the operator must seek contrast by a proper proportion between the degree of X-radiance and the length of the exposure.

The picture must not be made hap-hazard, but the *object for which the picture is to be made* must first be clearly in mind and the exposure-time carefully regulated to procure the kind of effect in contrast that is desired for the diagnosis. To secure sufficient contrast to show a bullet in the hip-joint would require only an exposure that would imprint the parts on the plate, but to show definition and contrasts in cases of impacted fracture, early disease of the bone, and certain other lesions, requires a predetermined position of the part on the plate, and a definite management of the dosage and exposure with the definite end in view. The mastery of these requirements denotes the expert.

But the novice who does not develop his own negatives will find a pitfall in certain photographic technicalities when they are not under his own control. A non-medical photographer, not knowing what the normal anatomy is or what object is sought in the picture, can heedlessly develop away a local shadow till it may be suspected to mean caries of the bone. A plate that is simply blank from sheer under-exposure may present a spot on the film that is taken for a gall-stone. These errors are totally different from the fallacies caused by distortion, and are avoidable by a study of fine contrasts. To instruct the reader in all that pertains to contrasts would lead us over the ground of several other chapters and be a useless repetition. If the importance and relation of contrast and definition in diagnostic radiography has been made clear by the above remarks we may consider that once started on the study the reader will never lose sight of it again in the increasing finish and refinement of his work.

Accessory Shadows as Aids to Diagnosis.—It is often desired to create an artificial shadow for the purpose of assisting diagnosis by better contrasts than the tissues afford. Pastes into which have been worked an excess of some metallic powder may be packed into a cavity, a cold abscess, the rectum, etc., and definition of outlines secured. A metal sound is sometimes skiagraphed in position to indicate direction or depth. A flexible spiral wire has been passed into the stomach in the lumen of a rubber tube in attempts to ascertain measurements, etc., with the X-ray. The gyromele may be similarly employed. A light roller-bandage with metallic bismuth-powder dusted in its meshes and bound around an arm, for instance, aids to bring out the contour in a stereoscopic radiograph. Charcoal, starch, and sugar, all create nearly the same shadow as would the equivalent of bone, and may be used in ways that will suggest themselves to special experimenters. Sulphur, lead ointment, and talcum are about as opaque as chalk, and as these are all available to the physician they offer a variety for the mixture of paste masses.

Benedict claims priority in the use of gelatin capsules containing reduced iron and also iron and bismuth. He first employed them February 9, 1897, " having had the matter in mind for some months." The idea occurred to many that if a capsule was filled with a somewhat opaque salt, say bismuth, its course down the alimentary canal after being swallowed could be observed with the X-ray. Any point

of lodgment could be located, and various diagnostic suspicions could be thus confirmed. Two German writers early reported observations with tests made on fourteen patients with gastric affections and recommended the method as an excellent means of diagnosis.

But later others improved on the make-up of the capsule by substituting for its contents of powder a solid lead shot. Take a large gelatine capsule, put into it a shot as large as it will take, close the capsule, and cover the surface completely with a smooth layer of dental gutta-percha, applied warm to secure adhesion. This is easily swallowed, and is not acted on by the gastric juice. If the capsule is filled with as long and large a piece of " soft-solder " or fuse-wire as it will contain instead of a round shot the shadow may give increased evidence of the direction of the course pursued. In a communication on the diagnosis of intestinal obstruction a writer says:

> " I have produced an artificial obstruction in the intestines of three dogs: one of strangulation, one by a twist, and one by a foreign body not opaque to X-rays. Each dog was given a lead capsule, and in all cases the exact condition could be made out in three hours after swallowing the shot. It could be seen with the fluoroscope during its passage, and could be traced gradually to the point of the obstruction in the intestine. It was not necessary to take a skiagraph. The diagnosis in each case was verified. I have swallowed a similar capsule myself to ascertain if it would pass freely without being affected by the digestive juices. It passed in two hours without any discomfort to me. I made a few skiagraphs in succession, tracing the pill in my own body, and it was very interesting."

On the other hand, intestines inflated with air become more transparent to the rays, and this fact has been utilized in some diagnostic procedures. Water also imparts another shading to the density of a hollow viscus. Those who need to experiment along these lines will be able to amplify the above suggestions in various ways.

Currie has made the following interesting " X-ray observations on hollow organs " illustrating the aid of accessory shadows in securing outlines of transparent parts. Due allowance must be made by the observer for the enlargement on the screen in proportion to the distance of the shadow-casting body. The instruction gained from reading this account can be applied to a variety of diagnostic uses.

> " A piece of furnace-chain was drawn through a stomach-tube until the eye was reached. Thus the rubber, which is partially impermeable to X-rays, was reinforced by the metal chain, which was completely impermeable. The tube was then swallowed by a subject, and observations were made with the fluoroscope.
>
> " Looking through the body transversely the chain could be seen

very distinctly in the pharynx, and in the œsophagus to a point a little below the clavicle. As the rubber tube was pushed in or withdrawn, its point could easily be noted, and in the neck each link of the chain was very distinct.

"The Crookes tube was then lowered to the level of the stomach, and the subject turned so that he faced it. The stomach-tube and chain were then seen by placing the screen at the inferior angle of the left scapula. The individual links of the chain could not now be distinguished, but the shadow was distinct. On pushing the tube into the stomach its point could be seen to emerge from the right side of the shadow of the vertebræ. It then glided smoothly downward and forward, and ultimately the lower part of the tube rested upon the greater curvature of the stomach in an almost horizontal position. The tube rose and fell with each movement of the diaphragm. By means of a heavy piece of wire placed upon the skin of the abdomen the course of the tube could be marked upon the surface. The lowest point of the stomach was found to be two and a half inches below the tip of the ensiform cartilage.

"The experiment furnishes an accurate method of marking the lower border of the stomach. By gradually filling the stomach through the tube its surface marking could be determined for any degree of distension. The possibility of watching the tip of the tube as it glides along the surface of the stomach suggests a method of observing irregularities of the organ due to congenital conditions, constrictions, tumors within or without the organ, etc. The extent of movement of the tube furnishes a means of determining the extent of the rise and fall of the diaphragm under different conditions. The facility with which the chain and tube are observed in the pharynx and a large portion of the œsophagus, should prove useful. Dilatations of the œsophagus could be examined by noting the various directions in which the point of the tube could be made to travel.

"The course of the œsophagus is often altered by conditions such as aneurism, new growths, tubercular deposits, retro-pharyngeal, and retro-œsophageal abscesses, etc. These would not, as a rule, be shown by the X-rays, but by watching the alterations in the course of the chain, their location could be determined, and in some cases their extent could be ascertained.

"This experiment is but one application of a general principle. The rectum, colon, urethra, bladder, vagina, uterus, nose, and all cavities accessible from the outside could be examined in a similar way.

"A probe introduced into the nose can be clearly seen throughout the whole extent of the nasal cavities, as the surrounding bones are so thin that they are permeable by the X-rays. By means of the X-rays it would be possible, under the guidance of sight, to grasp with metal instruments impermeable foreign bodies placed deep in the nasal cavities; a similar manœuvre would be possible in many other cases.

"These experiments suggested that of introducing small bodies, impermeable by the X-rays, with the food of some animal for the purpose of observing the movements of the food in the œsophagus, stomach, and along the intestinal tract. The feasibility of this procedure was tested by placing a capsule, containing a few small shot, in the pharynx of a cat. The shot could be seen as they rapidly descended the œsophagus and entered the stomach. By turning the cat over, the shot could be examined from every side."

Still other suggestions have appeared along the same line. It is said that the size, shape, and position of the stomach may be made out in the following manner:

"Take a soft rubber stomach-tube with a small eye. Fill the lumen with small shot of a size which will not fall through the eye nor close the lumen. The tube must be well weighted, yet not too heavy for comfort. It must be freely flexible also. When ready for the fluoroscopic examination have the patient swallow the tube to any desired point, while you observe its descent with the X-rays. When it has reached the most dependent portion and its contour is seen on the screen take a pliable rod or coarse wire and bend it to the same shape. Place it on the skin over the stomach so as to register with the shadow of the swallowed tube, and then mark its line with a dermal pencil. If the empty stomach be now inflated by means of a rubber bulb attached to the outer end of the tube the organ will appear as a bag distended with air which is transparent to the rays, and its outlines can be noted distinctly and drawn on paper. Any operator requiring to make this experiment would need sufficient ingenuity to adapt the technics to the case in hand."

It has also been stated that in cases of children changes in size and shape of the stomach after a meal may easily be made out by feeding bismuth subnit., with bread and milk. For further technics see chapter on examinations of the stomach and abdomen.

Examining Negatives.—However acquainted the reader may be with writings and X-ray half-tones in medical journals, he cannot be a judge of correct interpretation of X-ray negatives *until he studies the negative itself with a knowledge of the part radiographed, and of every step of the technique which produced the picture*, from the state of the tube to the photographic development. If the beginner can secure the assistance of an expert friend to point out to him the different shadows of a good original negative, and explain to him why they occur, wherein they differ, and what they mean, it will profit more than a lifetime of looking at reduced, obscure, and blotchy half-tone illustrations. A man not familiar with anatomy will not at first either produce or interpret well a series of radiographs of fractures; but a mere photographic expert, who is not a surgeon and is not familiar with lesions, may produce a series of radiographs which look well, but he cannot well interpret them. Again, the expert clinician will overlook important evidences of disease in the first radiographs he examines, until the X-ray expert points them out to him and he acquires expertness himself.

When you look at a negative with the glass side toward the eye the image is reversed from the position in which the exposure was made, and is seen as it will appear in a print. If, for instance, the part exposed was a hand with the palm down, the appearance will be as if the examiner was looking directly at the palm.

If, however, we look at the negative with the film side facing the eye, it is as if the examiner stood in front of the tube and looked at the back of the hand. The simplest and an effective method of examining some negatives is to lay the plate with the film side down on a smooth sheet of glazed and heavy white paper, with a good light in front of it. The paper should lay on glass or a smooth table, and press closely against the surface of the film. Transmitted light is not used for this examination. Many details will be brought out which do not appear when the negative is simply held up in the hand and looked at in the ordinary way.

A good reading-glass which magnifies the image may aid much in examining the negative in this manner, and helps relieve the flat appearance.

Another method of examining negatives may be improvised by any surgeon. Simply make a pyramidal box-frame similar to a fluoroscope-frame with both ends open. Make the small end about large enough to fit over the eyes. Make the large end large enough to press against the negative just inside its edges. The frame will exclude all light. To study a negative, simply press it with one hand against the large end of the box, press the eyes into the small opening, and with a black cloth thrown over the head to still further shield the eyes look toward any good source of light such as a window on a bright day, or a lamp, or electric-light in the evening.

It is important to impress upon the beginner the advantage of studying X-ray negatives through the aid of *transmitted* light and with *darkness in front of the picture.* Those who have not witnessed the result can have no idea of the advantages thus obtained.

Those who have modern fluoroscopes from which the screen can be removed by unclasping the hooks have a ready-made dark-box as above described for examining the negative. Simply take out the screen, place the negative against the large end and hold it up

toward the light. Look through the small end the same as in fluoroscopy. The view is one of the best that can be obtained.

A photographer's "retouching frame," large enough to take all but very big negatives, can be bought at supply stores for three or four dollars, and is a very superior means of examining X-ray plates. Simply face the light, lay the negative on the glass, shade the upper light with the top, and concentrate the light from below upward by means of the mirror.

In the examination of the negative study the following points:

How to best bring out all the details of the negative by both direct and transmitted light. There is considerable knack in holding the

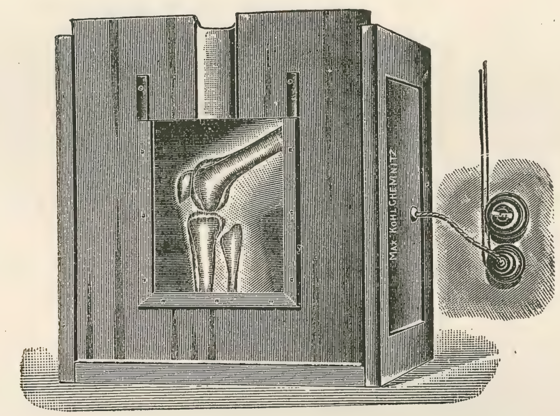


Fig. 14.—This figure very imperfectly shows a box for examining negatives with electric light inclosed behind the sliding front. The engraving is supposed to show a radiograph of the knee seen by transmitted light.

negative still, shifting its position, altering its relation to the light, and so on. Sometimes slight rapid movements will bring out shadows that do not appear otherwise. Study also:

How to know that you have a correct picture of a part.

How to read general shadows on the plate.

How to read overlapping shadows, and distinguish whether they are pathological, physiological, or due to slant of the rays.

How to translate special X-ray shadows into diagnosis.

How to distinguish between healthy and diseased structures.

How to distinguish between normal transparencies and the transparency of loss of substance.

How to collate knowledge of the case otherwise obtained so as to interpret the X-ray evidence correctly.

A *cradle-box* for the examination of negatives by transmitted light is one of the most pleasing adjuncts of the expert's outfit. Make a pine box sixteen inches deep and as large as your largest X-ray plate, say, 14 × 17. In this box install four sixteen candle-power electric-lights with an external rheostat to reduce or "dim" the light as desired. Face the box with a ground-glass front and swing it on a frame so that it can be rocked to any degree of a half-circle and fixed in the desired position with a set-screw. Out of plain black oilcloth now arrange four movable curtains which can be brought together in the centre from each side and from the top and bottom of the cradle. Use a free and long flexible cord from the lamps to the electric connection and the apparatus is complete.

In use lay the negative on the ground-glass face of the box and about in its centre. No matter how small a plate is to be examined the method is the same. Draw the four curtains up till they meet the edges of the plate and cut off all light except that which must pass through the negative. If the lower curtain is finished with a wooden bar which will fit in side slots of the frame the base of the plate can rest on this cross-bar very conveniently.

When the plate is in position turn on the lights and tilt the cradle to various test positions till it assumes the best relation to the operator's eye. Then vary the degree of light and study the shadows. Darken the room to a dim light.

To one who has never seen a fine plate with this advantage the effect is almost startling in its beauty. The plate is a "transparency" at its best. A dim light behind it will bring one set of shadows to greatest clearness; a brighter light will show forth still other effects. *No single-phase print, and no negative examined under ordinary conditions can approach the various and comprehensive effects brought out in the above manner.* The shifting of the cradle on an horizontal axis and the variability of the transmitted light reveals an X-ray picture in its highest diagnostic capabilities. It can be quite inexpensively made, and is a luxury to one who employs it.

Next, step back ten or fifteen feet and view the negative through a fine opera-glass giving high-grade definition, adjusted to an exact focus. The remarkable relief thus brought out is the nearest thing to a stereoscopic picture that I know of. It will be a revelation to those who judge X-ray work from prints or reproductions.

Examination of Radiographic Prints.—As looked at in the ordinary way these prints show to the least advantage. The aid of a large reading-glass will not only bring out the detail, but will somewhat improve the perspective. The picture will not look quite so flat. As a print shows a reversed position of the parts it will be helpful to the beginner to examine them with a mirror and good side light. Take

several X-ray prints of different parts of the body and compare the direct view with the normal (and more satisfactory) appearance seen in the *mirror* with a proper light. When the operator has become expert he will be able to judge a print in any relation to the eye, but in cultivating skill in interpretation the mirror view is exceedingly useful. Try it. In case of doubt make two or more careful prints from the same negative, as faint details may be saved in one that are lost in another.

X-Ray Atlases.—To aid both beginners and others to more rapidly acquire experience in the diagnostic interpretation of radiographs a number of large atlases have been published. Earlier specimens were rather crude, but recent issues show much better work and suffer less in the process of reproduction. These plates can never represent the original negative in value, but the operator who can study his own negatives and learn to allow intelligently for changes wrought by each step from film to print, block, and book, will derive help in many of his less common cases by having a set of classical reproductions with explanations for comparison. To enable the reader to judge how much a surgeon not yet master of all that pertains to X-ray technic may learn from this source of current literature, to which monthly additions are being made, we cite here a selected notice showing the scope of one, and there are already a number of others:

"Atlas ———. This atlas, which consists of forty-eight plates, deals chiefly with infantile and orthopædic surgery. The plates are described briefly in the accompanying text, and each of the four divisions of which the book consists is prefaced by a more general account of the particular subject that is dealt with.

"The first fourteen plates are devoted to angular and lateral curvature of the spine, one being taken from the side. Some of them show remarkably well the good effect obtained in certain cases by forcible reduction of the deformity and subsequent fixation. The authors point out the very great value of X-rays in making an early diagnosis; in distinguishing caries from other affections of the spine and from neuralgia; in localizing the exact seat and extent of the disease; and in furnishing definite evidence of the influence of treatment in procuring consolidation of the diseased structures.

"The second portion of the work contains illustrations of rickets, exostoses, osteo-myelitis, osteo-sarcoma, genu-valgum, coxa vara, and deformities, such as club hand.

"Fourteen plates are devoted to tuberculous disease of joints, chiefly of the hip, and many of these show the peculiar translucency of the diaphysis, which, according to the authors, is one of the earliest signs of incipient osteo-arthritis. Softening of tuberculous foci is shown to be indicated by a diminution in the darkness of the central portion of the affected area, and by the much greater extent and clearness of the peripheral zone. It is pointed out that osteophytes (like callus) are very often translucent to the X-rays and in consequence are very lightly shown.

"Special attention is drawn to want of distinctness of the inter-articular space often seen in cases of joint disease, indicating, according to the authors, the presence of granulation-tissue growing from the bones or the synovial lining of the joint and filling up more or less of the interior.

"The last twelve plates are given up to congenital dislocation of the hip-joint. Several of them are taken from the same case, before and after reduction, and some of them are of particular interest as showing, not only that reduction can be effected in certain instances, but that it can be permanent."

In the best of the publications not only are the plates made from negatives selected as the most successful out of many, but efforts are being constantly made at great expense to secure improved processes of reproduction. Some have been devoted to special anatomical studies of the different parts of the body, while others aim to trace development and growth of bones from the fœtus to maturity. These works are destined to form in time an immense pictorial library for physiological, anatomical, and pathological reference, and, having done readers the service of stating their value, it is needless to here review them further. They teach nothing of technic nor of apparatus, but they aim to classify and interpret results.

The X-Ray Picture not a Silhouette.—Over and over again writers have called attention to the fact that an X-ray picture was "a silhouette only." Others have belittled its importance by stigmatizing it as a "mere shadow." Scores of writers have taken pains to explain that it is "not a photograph."

These remarks will not bear scrutiny. Take a piece of black paper and with scissors cut out the profile of a hand. Paste it on white paper. You then have a silhouette. Does it look like a *radiograph?* Hold your hand between a light and the wall. On the wall may be seen a mere silhouette of the hand, but is it equal to a radiograph? Now, take one of the finer negatives of some complex part of the body produced with superior apparatus by an expert. Examine it by transmitted light with a dark foreground. Even use an opera-glass or a good reading-glass as described before. Now note the difference between the product of the X-rays and the mere shadow on the wall and the silhouette. The contrast in its revelations and in its delineated detail is as great as that between a sheet of white paper and a printed

bank-note. The radiograph reveals a series of superimposed and commingled shadows with lines and varying density. Depths are suggested to the trained eye, and contour is wonderfully seen in the stereoscopic X-ray picture. No photograph or product of the etcher's art shows more exquisite traceries and lights and shades than some of the best radiographs of bones. As a matter of fact, the high-water mark of modern radiography rivals as a picture and as an informing object-lesson the best of camera photography or engraving. The different purposes for which the radiograph is taken, and the unfamiliar nature of the information revealed by it, have led to the hasty conclusion that it is less of a picture than the familiar photograph. It is, in fact, among the highest type of pictures yet produced, and it has many years of development before it.

CHAPTER XVIII

AUTHOR'S X-RAY DIVERGENCE CHART

Directions for Uses in Scientific Radiography. A Study of X-Ray Divergence.

The explanatory description of this important aid to medico-legal accuracy in X-ray work is as follows: The Chart is a supplement to this course of instruction, fourteen inches wide and twenty inches long. It shows at a glance the following points of essential interest to the X-ray operator:

1. A plane diagram of X-light radiations from the anode focus point.
2. The rate of departure of X-rays from a parallel path at different distances from the tube.
3. The proportionate loss of right-angle shadows at different distances horizontal to the perpendicular axis.
4. The area of non-distorted field of observation at any distance from the tube.
5. The area within which a body of any thickness will shadow the right-angled relation of the part at a given distance from the tube.
6. The distance from the tube at which a part must be exposed to secure essential correctness and non-distortion for a diagnostic field of any given size.
7. The general area of *approximate* non-distortion on the plate.
8. The obliquity at all outside distances surrounding the central field of *exact* perpendicularity of radiation.

This Divergence Chart was designed by the author in November, 1900, and is now published for the first time. Its scale is limited for convenience to twenty inches as a working distance from the tube, and shows a maximum field at the base of fourteen inches diameter. Measurements of greater distances can easily be made by extending indicated lines.

The tube occupies a central position above a series of cross lines one inch apart which mark exposure-distances down to twenty inches from the Anode focus. The Cathode stream from the curved negative electrode impinges upon the platinum plate of the Anode, which is diagonally situated near the middle of the tube. From the impinging

point of the cathode stream (the focus-point) X-rays radiate out in straight lines through a half-sphere of space. The straight red line coinciding with the plane of the Anode, and the red half-circle four inches from the origin of the rays, mark the extremes of radiation, but in actual work we select and use only a small field out of the full half-sphere. The working field may correctly be any part of the illuminated space, provided that the plate or screen *is at a right-angle with the radius of X-ray which meets its centre.* Otherwise the shadows will represent acute or obtuse angles and there will be distortion from this obliquity. For convenience the Chart illustrates a central field fourteen inches wide, or the greatest extent of a 11 × 14 photographic plate.

The *diverging red lines* illustrate a plane diagram of X-light radiations from the Anode point of origin, or focus point.

The *central* red line shows the path of right-angle ray which will carry a non-distorted shadow to the plate at any distance from the tube. With equal divergence on each side of this axis fine red lines show the increasing slant of the shadow from the centre to the edges of the plate.

The *black vertical lines* mark the rate of departure of X-rays from a parallel path, and the proportionate loss of right-angle shadow at different distances from the centre and from the tube.

These lines on each side of the centre (numbered from one to twelve) mark quarter-inches of deviation from the perpendicular. The outer lines (numbered from twelve to twenty) mark half-inches of X-ray divergence, and the distance within which any given degree of divergence occurs can be noted at sight by means of the black cross-lines which mark the distance from the tube.

Thus, a shot situated at the juncture of vertical line eight would appear on the plate half an inch to one side of its true location if the plate was five inches from the Anode and the shot was an inch above the film. With the same relation between the film and the shot, but removing the plate to twelve inches from the focus, the distortion is seen on the chart to be hardly one-fourth inch, while at twenty inches the shot shadow is less than one-eighth inch from the perpendicular. The same principle applies to the surgical relation of joints, fragments of bone, normal parts, and the correct shadowing of all foreign bodies.

But a photographic plate is *flat*, and the true boundary of the X-ray light which streams out in diverging lines like the radii of half a sphere is the circumference of a sphere drawn round the same centre. Any *arc* of a semicircle drawn at any distance from the focus will cut the rays at an *equal length*, but a *flat plate* does not. Rays of *equal length* in all parts of the field are the *sine qua non* of normal shadows on the plate, and with unequal cutting of a curved boundary by a flat plane only approximate exactness in shadows can be attained outside the focus centre. This is the insurmountable barrier in practical skiagraphy.

To illustrate the curvature of the surface required to be in equal focus in all its parts we have drawn upon each flat plate (as represented by each cross line) an *arc* which meets the bisection of the cross line and the axis. *At this bisecting point the plate is in perfect focus*, but the chart shows how limited a part of a flat plane can be in perfect right-angle relation to the cone of diverging rays. The series of arcs show the increase of this area at all distances from the tube up to twenty inches.

As the curve of the arc leaves the flat plane of the cross line which represents a photographic plate, the degree of separation shows the increasing deflection of the shadow of a body in proportion to its location above the plate.

At the outer extremities of the arcs the limits of the diagnostic field of *approximate surgical accuracy* are reached. The *Approximate Diagnostic Field* is therefore all that area on the negative plate indicated by the arc coinciding with the exposure-distance. The picture on the plate beyond the true diagnostic field is useful to show the general relation of the field to the whole part.

The limits of the *Exact Diagnostic Field* depend on the need of showing the exact relation of the parts and vary with the distance between the surfaces of the denser structures and the film, and the remoteness of the tube. Knowing, then, his case and his needs as to securing nearly exact right-angled shadows, the surgeon has but to note the distance on the chart that this field requires him to make the exposure. Or, if the exposure is made at the standard distance of twenty inches the chart indicates the *relative* accuracy of the picture within and beyond the *exact* field.

The *Exact Diagnostic Field* is the area between those two red lines equidistant from the equator which pursue a course through the essential thickness of the parts undergoing examination sufficiently parallel to the vertical black lines to shadow the parts on the plate in as correct relation with each other as the diagnosis requires. Its area will thus vary according to the distance from the tube and the thickness of the parts to be skiagraphed.

When diagnosis depends on contrasts of light and shade and densities of parts instead of the anatomical relation the field may be much

wider, and a right-angled shadow is not indispensable as it is in the former case.

The more this chart is used by X-ray workers the more it will be appreciated. Knowing that his plate was correctly centred, and knowing the tube-distance from the film, the anatomist can demonstrate with the chart and the skiagraphed section of his subject the exact lines of divergence and the degree of accuracy represented in the picture, and thus give legal value to his evidence. This will do away with past complaints about distortion, and greatly increase the dependence on X-rays.

In future no surgeon will examine a case without the guidance of this standard chart even in private practice, and no case will be tried in court without its supporting proof of accuracy. When employed in conjunction with the author's "position finder" for centering the plate, and with my "landmark" included in the picture as evidence of the position, an X-ray shadow of a part can be interpreted with more confident certainty by anatomists. In other classes of cases, when the tube for special reasons is placed at an angle, the lines of the chart instantly convey to the eye the rectifying interpretation of the shadows and point to the section of the plate in actual relation to the object sought. In many ways the chart will serve the X-ray operator as experience discloses its utility.

It will be observed on the chart that the distance of the film from the source of rays increases with the departure of the *flat* plate from the *curve of the arc* of the radius. The *sides and ends of a plate* therefore receive a "shorter exposure" than the centre of the plate which is in the radial axis. This divergence of the rays is so great at close range that a large plate might be under-exposed ten, twenty, or even thirty per cent. at the corners while fully exposed in the centre. The old rule that a tube should be at least as far from the plate as the diagonal measurement of the plate is inadequate for exact work, while our chart shows at a glance the exact distance a plate must be to bring a required field within a required directness of radiation.

A Study of X-Ray Divergence.—From casual reading of X-ray literature the majority of surgeons are familiar with the word *divergence*, and the fact that X-rays are said to diverge thirteen-sixteenths of an inch in every sixteen inches of distance from the tube. But it is doubtful if many are clear in their understanding of what to do about this divergence, or what it may really signify in their own work. Let us try to clear the matter from confusion in the simplest way.

"Divergence" does two things. It causes the shadow of an object to appear larger than the real size of the object in proportion to its distance from the screen and tube; and it carries the shadow to the screen or plate in a slanting direction instead of down a straight line. To these two things are due what is called "distortion." If the rays were side by side (parallel) and had no slant they would go straight through a part and impress its image on the plate or screen without enlargement and with a normal position.

As a picture of parallel rays we may look at the vertical black lines on our chart and see that a bullet at the top or middle of any one of them would cast a shadow of the same size directly below it to a plate at any distance. The red lines diagram visible diverging rays to the eye, and though they do not represent all the X-rays they suffice to show that a body above the plate will cast not only an enlarged shadow, but a shadow that is displaced in a slanting direction so that it is not *under* the body, and the chart shows exactly how far any slanting ray will take a shadow out of a direct path. The chart is drawn in a single plane, but the rule holds good for all the lines of a cone.

What does it mean to "rectify distortions of position"? As X-ray pictures are shadows within shadows and not mere silhouettes, it "distorts" the relative relation of the parts if the shadows slant instead of the rays going straight through them. The only way to get the rays straight through a part so that every one of the combined shadows will bear the normal relation of life is to place the part in its long axis square with the axis of a central path of rays. If you want an "undistorted" shadow of your hand on the wall you hold it flat in the path of the light. Exactly the same principle applies to placing a part for examination in the path of X-rays so that "distortion" will be avoided. What is called an "accurate cross-section" of a body or limb is secured in this simple way. To "secure parallelism of the rays" is exactly the same thing in practice. All the writings which discuss these features of random X-ray work lead to the one simple fact that *a part ought to be placed with its long axis at right angles to the axis of rays which will pass through its centre in a straight line* instead of at a slant. It is no more trouble to do it than it is to do it a wrong way, and only requires grasping the idea and carrying it out in practice as a routine rule. There is absolutely nothing to prevent any surgeon from so placing the subject of his examination except the total lack of a desire to do it. As divergence is the cause of two things to be avoided in X-ray work —magnification and distortion—we will study the details of distortion more fully in the next chapter.

CHAPTER XIX

STUDIES IN DISTORTION

A CHAPTER DEVOTED TO CLEARING AWAY FICTITIOUS DIFFICULTIES.

LEST the word *distortion* become a bugbear to the beginner in X-ray work, let us study for a moment exactly what it means, and its relation to examinations for diagnosis.

X-rays which have traversed the tissues of the body mark the photographic film with shadows which are carried down from the tissues to the recording film in perfectly straight lines, which radiate from a point exactly as the lines of sight radiate from *one eye*. Our Divergence Chart is a plane map of these diverging lines. Spread it upon a table before you, and assume that any one of the black cross lines which indicate inches of distance from the focus, is a photographic plate. Now lay a small bullet upon the perpendicular red line in the centre and observe that, no matter whether you move it one inch or two inches, or four inches, or any distance up or down from a plate which may be either ten, twelve, fifteen, eighteen, or twenty inches or more from the focus, the shadow of the bullet falls like a plumb line to the centre *directly below it.* No matter how far the shadow travels from the bullet to the plate, it will fall directly *under* the bullet, and an incision in the same line would find it straight below the knife in the tissues of the body. In this case "divergence" of the rays does not cause any deflection of the shadow in an oblique line, because the bullet is in the straight line of an *axis* between the focus point and the plate, and there is no divergence in its field.

Leaving the imaginary plate at the assumed distance, say sixteen inches from the focus, place the bullet on the axis at the fourteen-inch cross line, which will make it two inches above the film. Move it laterally along the cross line to either right or left of the equator. It moves parallel with the film, but when it is a half inch, an inch, an inch and a half, two inches, or three inches, etc., from the equator trace down each *slanting* red line from the point where the bullet rests to the plate two inches below. The shadow of the bullet will not fall directly down the *vertical* black lines, but will follow the *slant* of the red lines. When the bullet at fourteen inches from the focus is actually five inches to the left of the axis, or centre of the plate, its shadow will fall on the plate six inches to the left of the centre. This, therefore, would be a displacement of one inch from the vertical axis, under the given conditions of distance from the focus and distance from the plate.

The Chart will instantly show every possible variation from a perpendicular line for every fraction of an inch to the right or left of the equator, and for every fraction of an inch of vertical distance. *It shows at a glance what many writers have explained by elaborate algebraic and geometric calculations.*

Compare the side displacement of the shadow of the bullet in proportion to its nearness to the film, and observe that there is no deflection at all if it is in *contact* with the film. Compare the difference in the side displacement of the shadow of the bullet two inches away from the film, when the film is six inches from the focus, ten inches from the focus, and twenty inches from the focus. Observe that the proportionate divergence of the shadow from the right-angle line between the focus and the plate *is less at the greater distance from the anode,* though the bullet actually remains the same distance from the equator. This guides the operator to an accurate choice of distance in making exposures to secure for a given area of tissues the smallest amount of deviation from a straight line. This is called *the elimination of distortion.* We have seen that all distortion is *eliminated* in the central axis of the rays, and it is perfectly easy to make all examinations and all radiographs with the essential tissues falling in or near the axis of the rays, and thus practically dispose of distortion.*

But there is one other side to the study of alterations between the position of the shadow and the substance in X-ray work. See how the red pyramid widens from the point to the base. If a piece of metal three and a half inches wide was placed five inches from the anode, and photographed with the plate twenty inches from the anode, the shadow would be *magnified to fourteen inches in width.* If the plate was brought up to six inches from the focus (one inch below the sheet of lead) its shadow would be magnified to only four and a quarter inches wide, or three-quarters of an inch in excess of life size. If, however, the lead and the film are both kept only one inch apart as last stated, but are dropped down the path of the rays, till the plate is twenty inches from the focus, the chart shows that the shadow will be magnified *less than one-quarter of an inch larger than the actual size of the substance.*

* See directions for the Author's Examining Frame.

The Chart then shows that tissues of any given thickness containing denser substances at an approximated distance from the plate must be examined or radiographed not only with reference to the *central axis* of the rays, but with reference also to the *magnifying* effects of the radiations in the cone-shaped field around the axis.

Now let us have a short session in practical object lessons. Set up the author's examining frame on its standard with the marking rods and balls in random positions anywhere between the tube and the fluoroscope. Clamp the fluoroscope to the frame to free both hands, and, comfortably sitting on a stool, observe the shadows falling on the screen as you turn the frame slowly on its pivot and hinges. At different positions remove the eyes from the fluoroscope and compare the line of the bars and rods as they appear to one eye with their shadows as cast on the screen. The amount of travelling that a fixed ball or rod will appear to do when swung aside from the axis of the rays will teach the necessity of correct alignment when living tissues are examined.

Next change the frame with its vertical and horizontal rods for the author's X-ray gauge with its round window and square crossbars. Set it up horizontal to the path of the rays and observe the shadow of the window through the screen while moving the base laterally from side to side and turning it on its own axis. Note the change of the round circumference of the window into a longer and longer ellipse, until, finally, it becomes little more than a narrow slit, as the gauge presents nearly edgewise to the focus. These studies of what is called the " distortion caused by position " of the object examined will be invaluable to teach the operator how to avoid it, because the moment the gauge is properly turned toward the rays so that they pass equally through it, the shadow of the ring resumes a normal circle.

Next hold the hand against the screen of the fluoroscope as if for an ordinary examination. Outside the second joint of the middle finger press the handle of a pair of small pocket-scissors. Make straight movements of the fluoroscope from side to side, and also tilt the screen obliquely up and down and turn it in various directions. Note how the shadow of the metal can be made to travel over to the index finger, which the scissors do not touch at all, or over to the little finger, or up the carpus, and down to the last phalanges, without in any way altering the actual position of the scissors upon the joint of the middle finger. This illustrates deflection of objects *out of alignment* and their exposure to slanting rays. It also shows *how to avoid this needless kind of distortion.*

In various other ways, which will suggest themselves, the physician may study distortion with specimens of bones, joints, and anatomical preparations. It is invaluable study. The philosophy of it all is, that in practical work the knowledge thus gained will enable the operator to interpret conditions in which some distortion is represented, to recognize unnecessary distortion when it occurs, and to so adjust the distance of the tube, the axis of the rays, and the distance of the part from the screen or film, that his own work will contain few of the "fallacies" that he reads about. The main thing is simply correct *alignment.*

The so-called "distortion" by X-rays is a radically different matter from the actually distorted image seen when we look into a concave or convex mirror. Aside from the special factor of *penetration* X-rays image the contour of a bone *according to the angle at which it is held*, precisely as does the normal sight of *one eye.* If the eye and the focus of the X-rays have the same alignment with the object viewed they will both exhibit the same results as to contour. If we sight a long bone transversely, or obliquely, or longitudinally, with one eye at twenty inches distance, we *see its contour in its different positions in the visual axis in precisely the same shape that the X-rays will image the shape on the plate.*

Yet when we look at a bone with an eye and hold the bone in different axes to the plane of sight we do not think our sight *distorts the bone.* We recognize that we only see a true contour of the object according to the position in which we hold it with reference to sight, and "fallacies" of the vision are not spoken of as if sight was intrinsically deceptive, distorted, and unreliable, dangerous to consider evidence in diagnosis, and something to "await improvements in" before we used it.

Nor is it a "fallacy" of either normal vision or the X-ray if we hold the bone we seek to examine *so far to one side of the line of sight* that we cannot see it clearly without turning the eye or the Crookes tube into better focus. The same laws of divergence and alignment of the lines of sight apply to the image on the single retina and the image on the screen and film. The difference in the visual quality of the two processes is great, but the mechanics of divergence, distortion, and enlargement are the same in both cases. It is well to bear this common-sense fact in mind when reading some alarming account of X-ray perfidy. You will not see the long axis of an object with either the eye or the X-ray if you hold only its short axis in front of you, and as X-rays cast shadows only by transmitted light, we must hold the object so that the axis we want to observe will cross

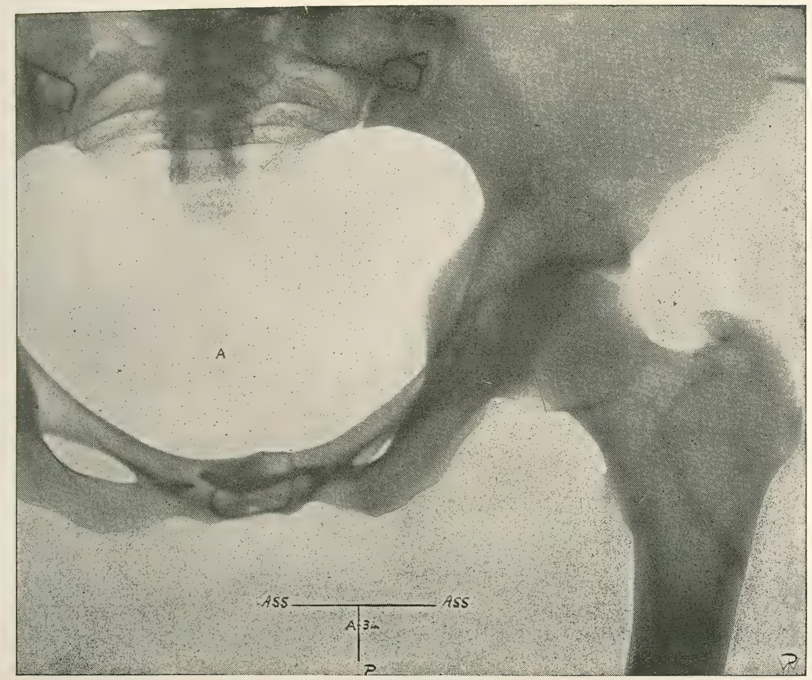


PLATE 41.—Plate One of Williams' Series of Hip Exposures. The series of four reduced hip-joints which now follows illustrate a normal and single hip and show, not the wild distortion of X-rays, but the need of the accurate placing of the anode over the exact part which the diagnosis requires shall be in the axis of the rays. The tube in all four pictures was 18 inches from the film. In this exposure the focus was over the letter A. This would do well for the pelvic basin, but not for the neck of the femur. See full description by Dr. Williams, of London, in this chapter. (Rebman, Ltd.)

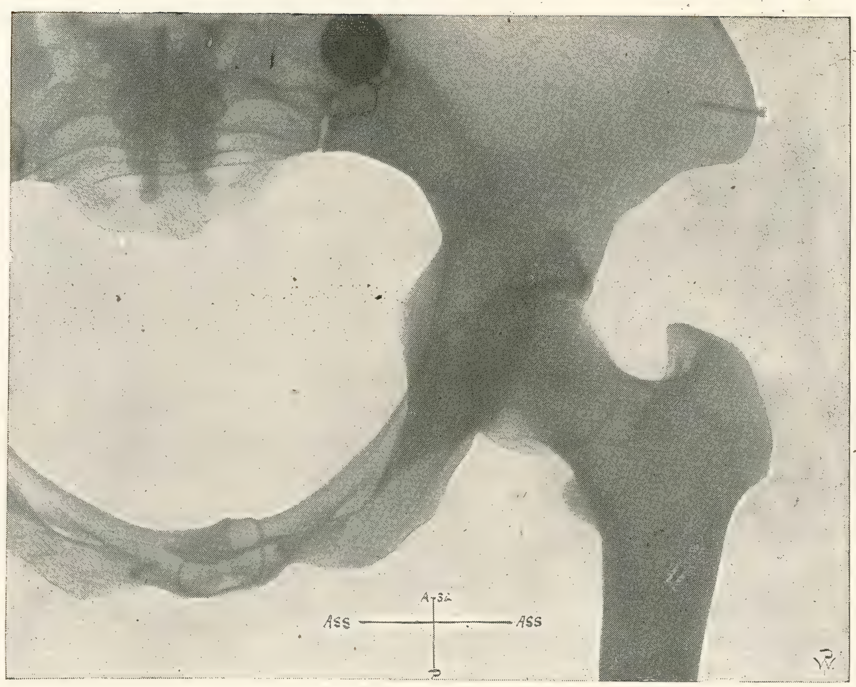


PLATE 42.—Plate Two of Williams' Series of Hip Exposuies. The tube was three inches above the level of the anterior superior spines in the mid-line. The result shows less neck than in the first exposure of the same part, and the angle of the neck, and shaft is greater than normal. See text for full description.

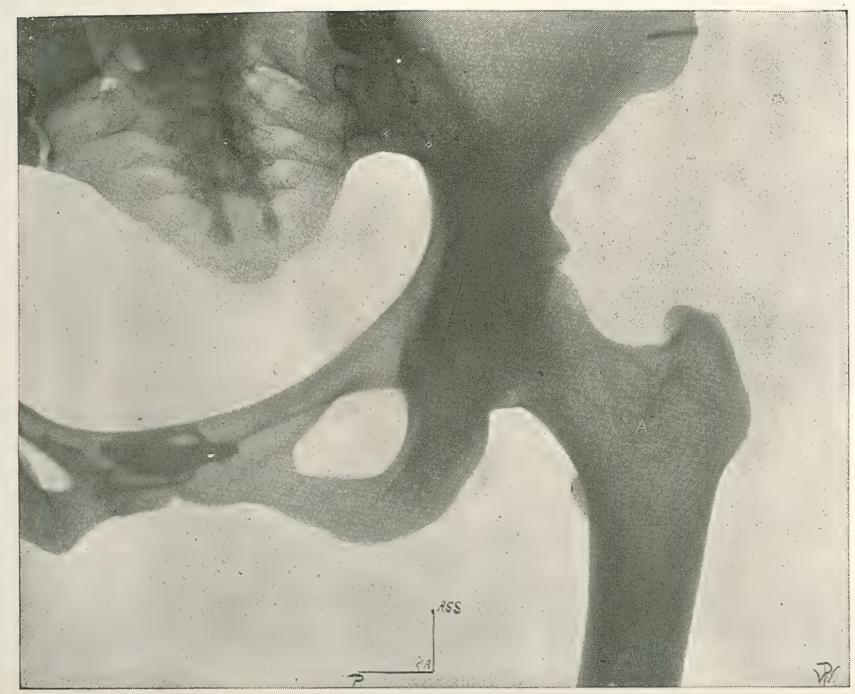


PLATE 43.—Plate Three of Williams' Series of Hip Exposures. The inner sides of the feet were placed together and the anode over the letter A directly on the centre of the union of shaft and neck. The result is therefore a normal neck with the proper angle. But this posture throws the shadow of the basin out of true, and again illustrates the fact that the axis of the rays can be in but one place at a time in a radiograph. It must be placed where the requirements of diagnos:s demand it and not simply at random over a general part.

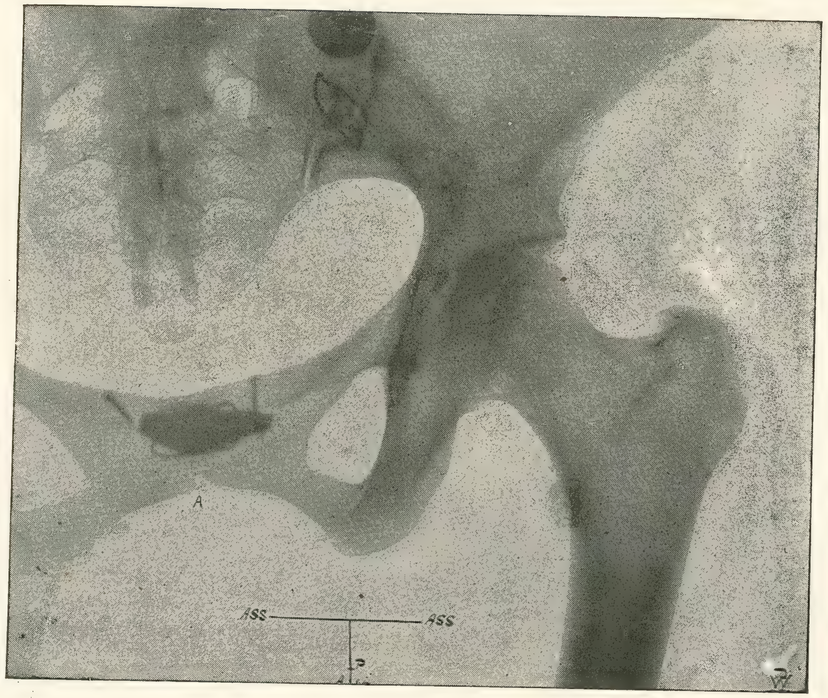


PLATE 44.—Plate Four of Williams' Series of Hip Exposures. The letter A shows where the anode focussed for this radiograph of the same hip. Were it not that the bone was rotated inward by placing the feet together, the greater tuberosity and head would be practically producing a false appearance, as of the condition termed "coxa vara." This does not exhibit the "inaccuracy" of X-rays, but only the need of focussing the vertical axis on the direct field of diagnosis instead of taking the essential part of the picture by slanting light that carries the shadow out of line. The operator controls the accuracy of his results. Study this chapter on distortion and it will be easy to avoid distortion.

the line of transmission. The obvious simplicity of the principle commends it greatly to surgical use.

A valuable article was recently presented by Williams, of London, and from it we may read with profit the following extracts, referring at the same time to Plates No. 41, 42, 43, and 44.

"At the Congress of the German Society of Surgery, in 1898, ——— showed a number of skiagraphs of the same normal adult pelvis from various points of view, which gave false appearance of deformity of the pelvis and femurs, produced by the tube being placed at several points above the subject, and by altering the distance between the tube and the sensitive plate. The majority were very much exaggerated, and such results would now be produced only by an exceptionally ignorant or careless operator. I have here four skiagraphs of the adult hip-joint. In each the tube was eighteen inches from the film, and the position of the anode was such as might be used by any ordinary operator with reasonable care.

"In No. 1 the tube was placed in what is probably the most common position; namely in the middle line between the hip-joints and three inches in front of a line joining the interior superior spines, with the heels on the table and the toes rolled outward. You will notice that the shadow of the head is thrown outward and slightly downward on to the neck, shortening that part; the more the toes rotate outward the more the greater tuberosity obliterates the neck, and if the rotation was about thirty degrees the neck would entirely disappear; the angle of the neck with the shaft is less than normal.

"In the next one, No. 2, the tube is placed three inches above the level of the anterior superior spines and in the mid-line. Here even less neck than before is seen, and the angle of the neck and shaft is greater than normal. The farther up the abdomen the tube is placed the more the head will join the shaft, and so all trace of the neck can be obliterated. Also the outer edge of the greater tuberosity will be projected outward and downward. In this picture the angle between the neck and the shaft is much greater than normal. In No. 3 the inner sides of the feet are placed together, and the tube was fixed over the angle made by a line about parallel with the middle line of the body drawn from the anterior superior spine, and another at right angles to this to the pubes. This places the tube right over the neck and gives the very least distortion; the angle of the neck with the shaft is normal, that is, 128 degrees. The obturator foramen in this view is nearly circular; in all the others it is more oval or even triangular. The mid-line of the sacrum is directed toward this foramen, and the shadows of the coccyx would nearly impinge on the brim of the pelvis.

"In the next picture, No. 4, the tube was placed one inch in front of the pubes in mid-line. Notice that the angle of the neck and shaft is more acute, and, were it not that the bone was rotated inward by the feet being together, the greater tuberosity and head would be practically producing a false appearance as of the condition termed "Coxa Vara," wherein the neck is practically at a right angle or less with the shaft.

"It is an interesting point to note that in young children the Y ligament which lies across the socket of the hip-joint shows in a skiagraph as a light space, it being cartilage, and, of course, more transparent to the rays, and normally the upper margin of the head should be opposite that point.

"Examples of skiagraphs failing to show what was expected are familiar to all. A distinguished surgeon read a paper before a clinical society upon congenital dislocation of hips, and had three skiagraphs, one of which I happened to see while he was reading his paper. The tube had been placed low down the thighs, and, therefore, projected the shadow of the neck upward. I spoke to him hurriedly, and that picture was not handed around. Another skiagraph was taken next day with the tube in proper position, when the hip-joints were found to be normal."

CHAPTER XX

THE AUTHOR'S X-RAY PENETRATION GAUGE

A Standard Measure of X-Radiance. Recording X-Ray Intensities. Standardization of the Gauge. Penetration Register. "Radiometers."

This practical instrument substitutes for the unequal eye and doubtful judgment of different operators a mechanical measure of X-ray penetration, in both photographic and fluoroscopic capacity. It settles several disputed points. It affords a definite method of testing fluorescing screens and Crookes tubes, and of standardizing the degree of X-light at required efficiencies. It makes possible a uniformity of results in X-ray negatives by determining the relation between exposure-time and the state of the tube. By its measurement and record, a surgeon in London can reproduce a particular degree of X-radiance reported in New York, and with perfect exactness can adjust his tube to the same efficiency and duplicate the same work. It completes the solution of the problems of standard light, standard postures, and standard time of exposure, to secure standard results on the negative. With equal photographic treatment during developing processes, the interpretation of X-ray shadows may now start from a more definite basis.

Of the many pocket devices called radiometers, photometers, etc., all that I have formerly seen cover but a small part of a large fluorescing screen, and allow the eye to fill with light from the surrounding field. They are pocket toys without scientific value. My own instrument is an altogether original and different thing. It is constructed as follows: A plate of lead is sandwiched between two plates of brass, making a solid metal base six-sixteenths of an inch thick. This base is made larger than the screen of the given fluoroscope, so as to shut out all rays except those passing through the window. In the centre of the base is cut a round window three inches in diameter.

Four wires next make cross-bars at right angles within the window. External to the window are twenty shutters of twenty-eight gauge sheet-brass stamped and numbered. The set of shutters is swung on a pivot, so that one at a time can be cut out from interference with the rays, or inserted as desired. Each shutter is four inches square, and a set screw on the pivot permits shifting them to suit. The lower side of the base is finished with a ledge at right angles on which to rest the frame of the fluoroscope. A pair of clamps at the top hold the screen or fluoroscope in position, thus leaving both hands of the operator free. By a heavy flange underneath the ledge the entire instrument is fitted to a telescoping brass standard, which can be raised or lowered to the level of the operator's eye for sitting or standing observations. A second post at one corner of the shutters catches them as they are turned back from the window.

To use the instrument clamp it on the standard, place it in the path of the rays, at the desired distance from the tube, and start the tube into action. Tests can then cover the following nine points:

1. The comparative efficiency of different tubes.
2. The comparative efficiency of different exciting currents from different apparatus with a given tube.
3. The comparative efficiency of different "doses" of current from any one apparatus with any tube.
4. The maximum (or any) radiance of any tube with a given current.
5. The *defining penetration* of any degree of X-light for record or reproduction.
6. The standardization of exposure-time for standard distances with given densities and thickness.
7. The law of inverse squares as not related to X-radiance.
8. The quality of any new or old fluoroscope of any make or material.
9. The relation of photographic activity and fluoroscopic efficiency to a given degree of X-radiance and to each other.

To test the quality of a new fluoroscope or to detect possible deterioration in an old screen, set up the gauge six inches from the tube. Then operate the tube with a small currrent, and only generate enough light to barely outline the ring of the window through two shutters. If the radiance of the tube used is not easily reduced to the exact point increase the distance between the tube and the gauge until the shadow of the ring is at its faintest visible outline. Make this test and all others requiring accuracy in an entirely darkened room. Keeping the tube and gauge in the same relation, compare now the definition of the window rim with each screen at hand, and it will plainly appear which fluoresces best. The percentage of difference

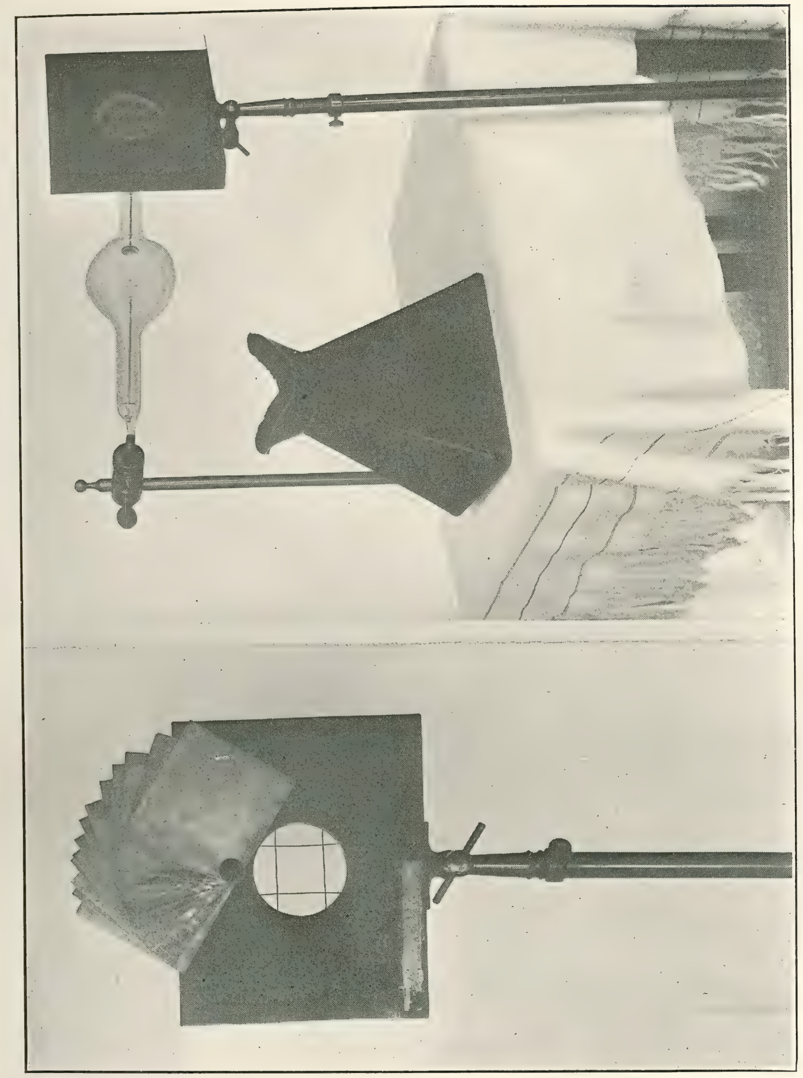


PLATE 45.—Author's X-Ray Gauge. Figure at left shows gauge set up on standard with shutters up and window with bars exposed. This side of the gauge faces the tube in use. On the right is seen the gauge in position for tests. Level the window with the focus at the desired distance from the anode, cover the window with the set of shutters, clamp the fluoroscope on the ledge of the base, and start the tube into action. Then make measurements as taught in our text. The gauge gives a definite record of both penetration and definition and is mathematically exact when employed under correct conditions for fine fluoroscopy. See text for full description.

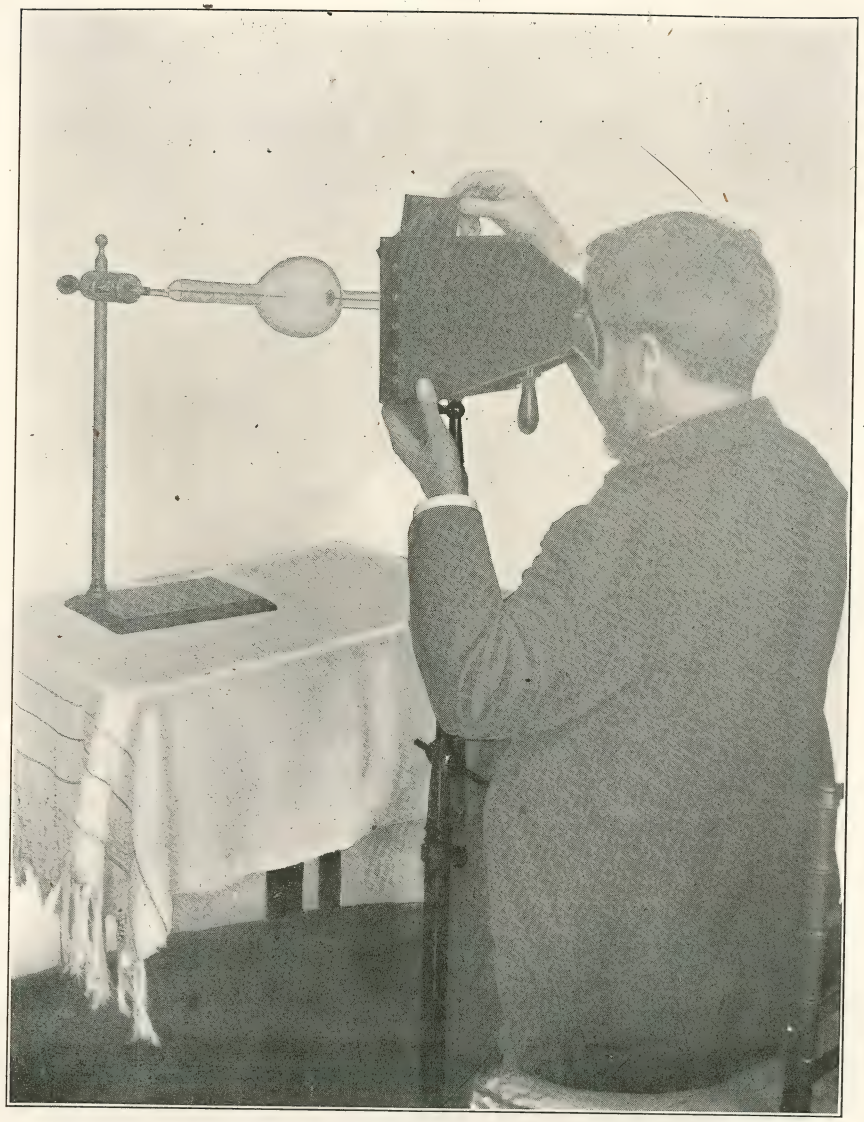


PLATE 46.—Author's X-Ray Gauge. This plate shows manner of shifting the shutters, one at a time, with the right hand while observing the effect of any degree of radiance upon the window and bars of the testing field. The operator sits in a chair with gauge and tube levelled to suit convenience. This is the only adequate and simple "meter" of X-radiance yet devised. By aid of the text and Instruction Plates any one can use it as taught. It is one of the prime necessities of scientific work with X-rays.

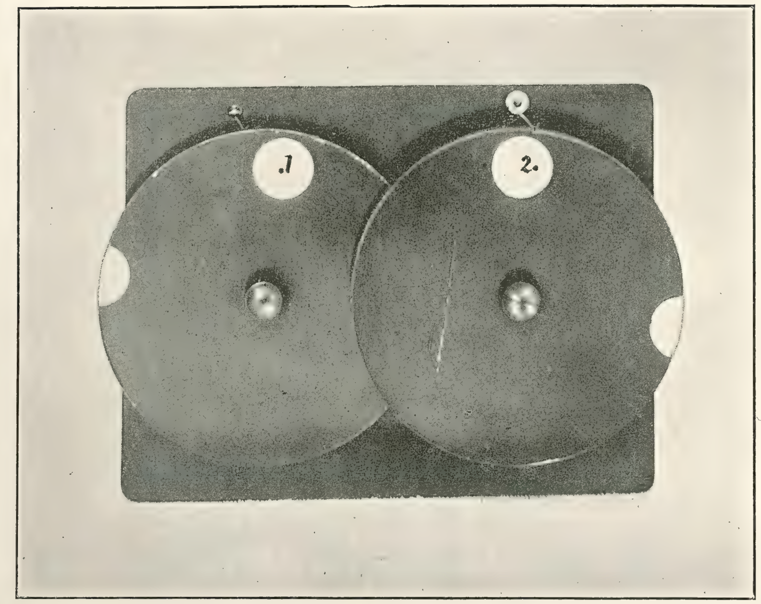


PLATE 47.—The X-Ray Actinometer. This ingenious device has a base which fits in the box of the regular fluoroscope after removing the screen. In the centre of the base is a small fluorescing window the size of a silver quarter. Upon the base are two revolving wheels. One is filled with ten layers of thin tin-foil. The other has ten layers of foil ten times as thick. To test the degree of radiance take out the regular screen and set the Actinometer in the fluoroscope. Clamp it on the front of the author's examining frame or on any convenient stand which will hold it in position at any measured distance from the tube. When the metal post in the centre of the miniature screen of the window casts a round spot shadow the base is square with the axis of the rays and ready for the tests. Next turn the wheels till the foil covering the window which fluoresces is just short of complete opacity. Then note the number of layers as marked on the registering window and the result is the penetrating capacity of the radiance as measured by the instrument. The windows of thin foil are marked .0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1. The windows of thick foil are marked 0. 1. 2. 3. 4. 5. 6. 7. 8. 9. 10. The two wheels give a test range of 100 variations of penetration and densities. It was originated by the Bario-Vacuum Company, of New York, by whom it is made. It embodies very ingeniously the important principle of excluding all light around the testing field as demonstrated in the author's gauge. The plate shows the base of the instrument facing the reader with the fluoroscope hidden behind it in the line of sight.

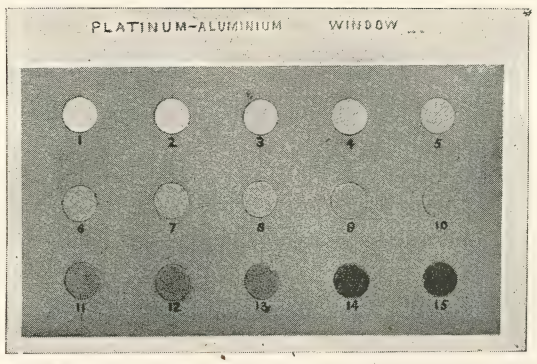


PLATE 48.—Many X-ray operators have employed test-plates with graduated windows like the above to measure the penetration of given rays. This cut is reproduced from a very elaborate article on the study of X-ray penetration, but a much clearer study could have been made by the author's gauge described in this chapter. The one fact that the whole field of the above windows is in the eye at the same time deprives the device of accurate value.

can also be very accurately determined by means of the shutters, and by distance. See Plates No. 45 and 46.

To further test screens for definition in addition to illumination, increase the light of the tube until the bars show best. Then compare sharpness of shadow with each screen. Both makers and users of fluoroscopes can thus standardize the highest attained efficiency, or note the defects of inferior screens. Records of these tests can be kept. Screens which have been in use for several years can be compared with new screens, when deterioration is suspected. The gauge is a practical necessity in the workshop of every manufacturer who makes either fluoroscopes or Crookes tubes, and should be in the office of every dealer who shows X-ray apparatus to customers. To the individual operator it is indispensable.

To test the maximum radiance of any tube, throw the set of shutters over the window, and stand the gauge at sufficient distance to obliterate all transparency of the field. Then slowly raise one shutter after the other, until the ring is dimly outlined. Next vary the exciting current and attempt to increase the light of the tube. If the gauge shows no increase in the brightness of the field shadow, the number of shutters over the window together with the distance between the gauge and the anode, will record the present capacity of the given tube. If the efficiency of the tube is increased, add shutters until they again nearly obliterate transparency, and record their number.

Next repeat the same test with reference to ascertaining the greatest number of shutters through which the entire shadow of the four cross-bars is defined. The measure of the working efficiency and defining power of the radiance at any given distance is the number of shutters of the gauge through which the shadow of the cross-bars can be made out with the fluoroscope.

To reproduce the same intensity of light at any other time, with the same or another tube, to secure a similar efficiency of penetration, refer to the record and adjust the radiance to the same distance and the same number of shutters.

It is important to the student to recognize the difference between *defining-power* of X-rays and mere diffused luminosity. The gauge is a beautiful test of this difference. Imagine yourself in a strange and very dark room filled with unfamiliar objects. A small candle will throw a diffused light throughout the room, and enable you to walk through it toward an object, but it will not define its details to the eye at a distance. The light has a low defining-power. To distinguish letters, the candle must be held close to the page. While such a glow will relieve the darkness its small practical working-power is general and not specific.

Now slowly turn up a gas-jet in the same room. As the light gradually rises in working efficiency coarse outlines of objects take the place of mere masses of shadow. A little higher working power and details appear to the eye. The working power required for a given purpose will be in ratio to the fineness of the definition of detail. An efficient light will enable you to read fine print at a normal distance from the eyes.

The philosophy of developing working-power with X-ray light is exactly the same. A tube may diffuse a general glow through the fluoroscope, yet have no better defining-power than the little candle in the dark-room. With a little increase of current and brighter X-rays we may see transparency commence through a large number of shutters covering the window of the penetration gauge. But not until the transparency is sufficient to do *defining work* does it become of practical value with the radiograph and the fluoroscope. The difference between a mere luminous effect of the rays and practical defining efficiency will be from four to six shutters of twenty-eight gauge thickness at twelve inches.

Operators who have not witnessed the demonstration of such a test have failed to recognize the cause of non-success in making examinations or radiographs with rays of less working-efficiency than the distance from the tube requires.

For practical standard work with tubes above an efficiency of X_4 with the gauge at twelve inches, the regular No. 28 set of shutters was selected by the author as a satisfactory thickness after four years of experience and numberless tests. For low-efficiency tubes requiring a finer discrimination, a second set of shutters is furnished of No. 36 Brown and Sharpe gauge which are about half the thickness of the others. Each is stamped from one to twenty, so that the number over the window can be known at a glance without counting. The set of thin shutters affords finer discrimination between different degrees of X-radiance, and is therefore especially adapted to testing low tubes or any tubes at unusual distances from the anode.

To compare the efficiency of different tubes, both for penetration and definition, use a definite exciting current, a definite distance between the gauge and the anode, and note the first perceptible appearance of the window for *commencing penetration*, and the first sharp appearance of the bars for *full penetration and definition.* The number of shutters required by each tube, other conditions being equal, will measure the difference in efficiency. In this way the author has rapidly tested twenty-five tubes at a time. No maker of tubes should be without this testing-gauge.

To test the comparative efficiency of different exciting currents with a given tube set up the maximum action of each and apply the same test.

To test the relative reduction of intensity in proportion to the increase of distance from the tube, establish the maximum radiance with the gauge two inches from the tube-wall. Note the number of shutters through which the window can first be outlined and the number through which the bars can be defined. If the bars are visible through all the shutters, as will be the case with a fine tube, move the gauge back till distance creates a zero point of light and record the number of inches between the gauge and the anode. Then lift one shutter and note the increased entrance of light. Lift a second shutter, note the increased light, and move back the gauge till the distance again reduces the transparency to zero. Record the exact distance, lift two more shutters, and move back the gauge till the light is dimmed to zero. Repeat the steps till all the shutters but one are removed. The relation of distance to the intensity of X-ray penetration will be indicated by the shutters. It was early stated that X-radiance followed the law of inverse squares. This is now known to be an error. Tests with the author's standardizing gauge will define the facts in feet and inches. With this gauge we can rate X-ray light as practically and correctly as we can measure any other light.

As a corollary to the above we arrive at the means of inaugurating scientific standards of time and distance in X-ray photographic exposures for each part of the body. A given degree of X-radiance, up to the maximum, can be practically regulated by any operator who can regulate the dosage of his exciting current; or a shunt regulator can be employed. It can be ascertained by tests that at a standard distance—say, twenty inches—parts of approximate thickness and density require a certain degree of X-light, for a certain exposure-time, at a certain distance. For the thicker parts of the body a record establishing the requirements for certain results would save multitudes of guesswork trials with feebler rays, and the cost of many failures and disappointments.

Any institution having high-efficiency apparatus, adequate experience, facilities for standard development of a negative, and command of clinical material, could work out the different "shutter-powers" required with reference to thickness and age of bones and different parts of the body, and publish the ascertained ratings for the benefit of the profession. The guesswork of the present would then be replaced by methods of precision. The missing link in the standardization of radiographs would then be put into the hands of every expert and beginner, and with the correct fixing of postures to eliminate distortion the popular chaos which has existed in this field of surgical examination prior to this date would give place to methods of scientific exactness. The author lacks time to do this.

Recording X-Ray Intensities.—In private experiments and in the many uses which the individual operator will make of this gauge the records made should note the measured distance between the surface of the gauge and the focus point of the rays, the dosage of the electrical current, the number of shutters through which light is first visible, and the number of shutters through which the bars are first defined, together with the resistance vacuum of the tube. If a Static machine is used, record the speed of the plates and exactly how the current is interrupted, with reference to spark length and polarity. If the direct constant current is taken from the prime conductors the fact should be noted. All these details can be entered in a single line by means of a few abbreviations and figures. Single letters will indicate the leading points.

The degree of radiance itself is indicated in the most practical and simplest manner, by simply adding the number of shutters to the letter X, as X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_{10}, X_{12}, X_{15}, X_{18}, X_{20}, etc. If other factors were always equal the mere mention of X with its proper exponent would furnish standard ratings for published reports and private work. But as the other factors are variable, it is necessary in a report to state the distance from the tube at which the degree of light was measured, as well as the vacuum of the tube which discharged the light and the dosage of the electric current which created it. When, however, in ordinary work it is only necessary to reproduce a certain degree of X-light with the operator's own apparatus, and at his preferred distance, it is only necessary to know the X-rating and adjust the tube till it produces the same.

Standardization of the Gauge.—To constitute this instrument a *standard official gauge,* so that all reports would have the same meaning, it is only necessary for all manufacturers to adopt the standard shutter of twenty-eight Brown and Sharpe gauge for the thicker set, and thirty-six B. and S. gauge for the thin set. Unless a uniform standard is adopted experiments will only have an individual value. The gauge, however, is not designed solely for scientific experiments, but is a practical working instrument for daily use with all who do X-ray work.

My now historic "Manual of Static Electricity in X-Ray and Therapeutic Uses," written in February, 1897, refers to my use of several layers of sheet-metal covering the entire fluorescing screen in measuring X-ray effects. The personal instruction of the author to physicians and surgeons for the next three years demonstrated the principle of this gauge. In 1900 I had it made up in the present standard form. It at once occurs to many who theorize about the matter that *brass* varies in its alloys, and that a pure metal, such as electrolytic copper or pure tin, etc., should be selected for the shutters. Practical experience shows that this theory is a refinement without value. The fluoroscope and the human eye cannot carry discriminations of degrees of light to so exquisite a point as to note the difference in ratios of alloy in different sheets of brass of the same thickness. Brass was chosen because it is a universal and cheap metal, easily worked, always obtainable in sheets rolled to standard gauge, and can be supplied by dealers anywhere. Its commercial convenience outweighs theoretical drawbacks which have no weight in practice.

Remarks.—This practical and reliable measuring instrument disposes of several theories about tubes and their differences. It makes the maker of tubes sure of his product and enables the buyer to select or reject them with precision. It weighs a tube in a balance of infallible accuracy, and mistake or deception is impossible. If found wanting, the gauge measures what it lacks. It is an indispensable part of equipment. To be without it in scientific X-ray work is somewhat like being at sea without a compass or sailor's log. To possess the gauge is to know exactly what tube, current, and screen are doing, and with this knowledge radiography becomes more nearly definite and certain.

The question is often asked why a tube may be good with a screen and poor for negatives, or why, of two tubes that appear to act just alike, one will make a good picture and the other fail. The measurement of tubes with this gauge removes these questions from discussion. A maker brought the author two exactly similar plain tubes for tests. Both glowed with nearly the same fine green luminosity of the glass to ordinary observation. The casual fluoroscopic glance at the hand was the maker's test. He remarked that they were both "good tubes." One showed the hand a little brighter than the other, but the usual moving of the screen back and forth in these observations ignores measured standards of distance and the eye notes only gross light and shade. Definite tests with the gauge at a fixed distance of twelve inches proved that one tube showed the bars through only *two* shutters, while the other showed them through *twelve.* The difference of ten shutters in the capacity of two tubes which looked near enough alike to deceive an experienced manufacturer indicates what the different results would be on a photographic plate. An exposure with these tubes for the same time, at the same distance, with the same current, would not be the same thing at all. To be alike, the X-radiance must be equal. The many crude ideas remaining extant in regard to supposed differences of photographic activity between different tubes and the same tubes at different times, are the result of working without this instrument, which affords an exact measure.

Penetration Register.—The Author's Penetration Register is designed to mark on the negative the *total penetration* of the exposure. Such an automatic registering device would appear to possess value in medico-legal cases, or in any case in which it was afterward important to know, or to prove how long the patient was subjected to the action of X-rays.

It consists of a graduated series of layers of standard gauge No. 28, sheet-brass, the same as the standard shutters of the author's penetration gauge, or X-ray meter. The layers run from one to eight in the sample, but for high intensities of radiance this number can be greatly increased. Numerals attached to the base indicate the number of layers penetrated during an exposure. The last figure which shows on the negative registers the total penetration. For practical use simply place it on the plate outside the wrapper and in close relation to the diagnostic field but outside of it. See Frontispiece.

This register may also be made useful in making tests to become familiar with average exposure-times for normal penetration with the apparatus in your own office. It may be objected that such a piece of metal on the plate will unbalance the development of fine shadows, but in cases when the register would be employed this would not be a momentous drawback.

Photometers and Radiometers.—These two words and also "Ray-meter" and "Skia-meter" have been applied to devices for roughly noting the penetration of the rays from any given tube. They are usually made with increasing layers of thin metal backed by lead numerals, or a bar of metal with a series of holes. The indicating numeral or hole on the border-line of opacity will mark the thickness of metal through which the rays show light. A number of writers have described variations in the device and its uses. An elaboration of the *skiameter* for quite a different purpose is described in another section.

When, however, the small aluminum "ray-meter" is observed through a fluoroscope the eye is filled with the luminous field, which

is usually much larger than the area of the meter. Fine discriminations of the degrees of shadow are thus lost, for the eye must be confronted by a dark field in order to detect in it the last fading of a dim shadow.

As commonly used these pocket devices and the fluoroscope are shifted in the hands of the operator, and no definite distance or relation to the tube is represented by the test. Being random, it signifies little when done. In marked contrast to these devices of casual value is the author's standard penetration gauge. Excluding all conflicting light from the entire field of test, and using a standard measured distance from the tube, it becomes a more scientific instrument of greater precision as a ray-*meter* than any other which has come to our notice.

CHAPTER XXI

THE AUTHOR'S DISTORTION LANDMARK

A Device for X-Ray Negatives. Medico-Legal Proof of Position and Distance of Tube During Exposures. Special Landmarks.

Where was the tube (and the X-ray focus) when the negative was made? This question may sometimes have medico-legal importance, but at all times the surgeon wants the information for diagnosis. The instrument to be described answers the question with scientific precision. See Plates No. 49 and 50.

1. It automatically certifies on the plate to the distance of the anode and the perpendicularity or slant of the axis of the rays.

2. It certifies to any displacement of the shadows of the proper diagnostic field caused by an inaccurate position of the plate or tube during an exposure.

3. It images on the plate the direction and amount of all deviations of the axis of the rays from the essential perpendicular.

4. It indicates an exact measurement of the distance of the anode from the film, so that a witness in a case in court who testified that the tube was at some other distance would be refuted by the internal evidence of the negative.

It is impossible to tamper with this evidence, or alter its plain findings if the landmark is used as designed. If fraud was undertaken, the obvious deviation of the shadow when confronted by a standard landmark would convict the witness of the attempt. In any case, the landmark will not only stigmatize fraud, but will throw careless guesswork out of court and compel a more correct picture of the part. An accurate picture must shadow the parts in the relation which appears when the path of the rays forms a right angle with the plane of the negative. Any deviation from an exact perpendicular creates proportionate obliquity and mars the diagnostic interpretation of some pictures. When the plate has been exposed after the usual precaution to insure perpendicular rays upon the part, the shadow of the author's landmark on the negative affords final and permanent proof of the accuracy or error of the preceding steps.

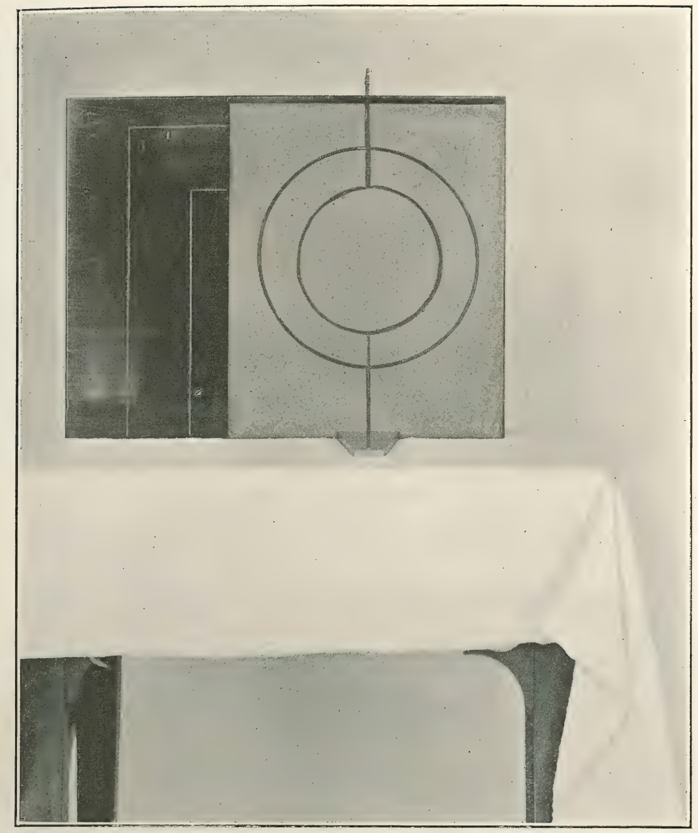


PLATE 49.—Author's Distortion Landmark Seen from the Front. The landmark is on the wrapper of a photographic plate which is on the brass base of the Author's Position Finder. The upper and lower cross-bars are in register and show as one shadow. The relative sizes of the two circles appear as they faced the camera. At twenty inches from the focus of the tube the divergence of the rays brings the upper and smaller circle into register with the lower and larger circle so that the shadows merge if the register is exact, or by their deviation prove the precise amount of "distortion" that occurred. See frontispiece for example of result in radiograph. See next plate for instruction in method of use.

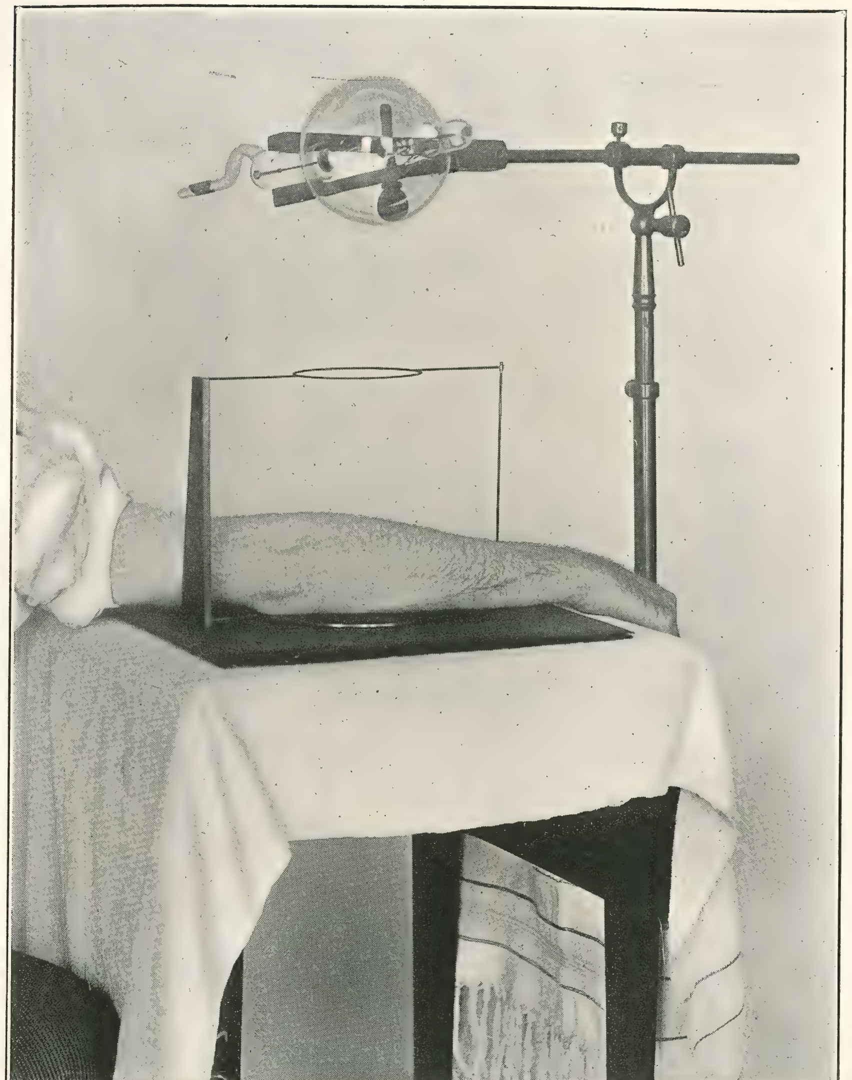


PLATE 50.—Author's Distortion Landmark. Method of use. This Instruction Plate shows the tube centred at twenty inches over the photographic plate on the base of the Author's Position Finder, as taught in the text. In the radiograph that will result from this exposure the negative will contain medico-legal proof of the position and distance of the tube, the field of the axis of the rays, and the degree of "distortion" present, if any has been caused. See frontispiece for example of radiographic evidence thus obtained.

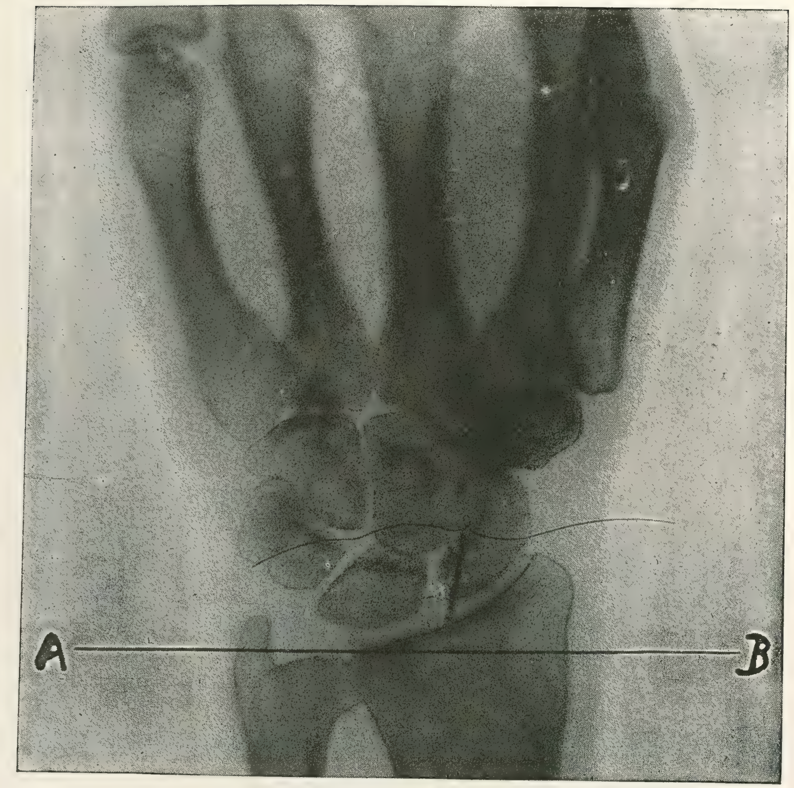


PLATE 51.—Illustrating a normal wrist in which a piece of needle has been imbedded. It also illustrates the method of marking a "diagnosticating" line at right angles to the long axis of the arm when studying radiographs of old injuries of the wrist. "This line is the only sure safeguard for rightly interpreting old healed-up fractures of the lower end of the radius. The whole of the articular surface of the radius, when in its normal position, is on a plane situated on the hand side of the diagnosticating line. When the radial styloid is on a level with that of the ulnar it is considered to establish the diagnosis of a Colles's fracture." The loop of wire seen in this picture was employed to localize the point of entrance of the needle. (Rebman, Ltd.)

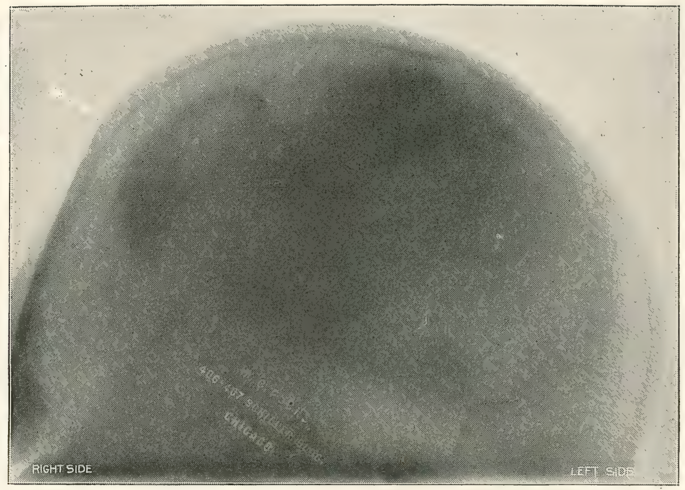


PLATE 52 (1).—Cystic tumor in the brain in child who was blind and partially paralyzed. Arrow in upper left-hand corner points to the tumor. The plate below shows the lateral cross-section of same case, while this plate gives the antero-posterior view. Compare both radiographs. The reduced half-tone loses much of the original negatives.

PLATE 52 (2).—Lateral view of above case of cystic tumor in the brain of child. Case operated on and recovered, verifying the radiographs.

X-ray work may be considered *accurate* when *it attains its object.* In some pictures the trained eye of the expert observer can note at a glance the slant of the shadows and deduce from them the position of the tube without a registering landmark, but the adoption of a standard landmark to certify on the plate the relation of the axis of the rays to the plane of the part examined will do much to remove doubt as to how the anatomical relations of the recorded shadows should be interpreted. For this purpose, when needed, the author has devised a pair of thin steel circles mounted rigidly on a support as shown in the Instruction Plates. As the majority of radiographs are made on films not smaller than 8×10 the base circle is seven inches in diameter. This is large enough to easily embrace all the main diagnostic field on any size of plate, however big, within which the shadows show the minimum of distortion, and is fully equal to the field of the ordinary fluoroscope. Therefore, this diameter has been selected for the lower register in average work.

The upper registering-circle mounted eight inches above the lower circle has the diameter (four and one-fourth inches) shown by my divergence chart to coincide with the lines converging from a seven-inch cone toward the anode at the standardized distance. With the base of the cone twenty inches from the anode, the cross section at twelve inches from the anode will be four and one-fourth inches, as shown by the chart.

Before using this register in radiography become familiar with its action through the fluoroscope. Observe the shadows cast on the screen by the circles when the larger one is in contact with the fluoroscope and the upper register is approximately in line with the tube. Note at once that the shadow of the circle in *contact* with the photographic plate will be sharp and clear. Its shadow, therefore, identifies it beyond question. Note the hazy and enlarged shadow cast by the distant circle and you will recognize it without fail when it is similarly registered on the plate in a skiagraph. Now shift the device in all directions out of the axis of the rays, and note how the *changing relations* of the two shadows indicate the *position* of the focus of the tube. Remove the eyes from the fluoroscope and prove the position of the tube till at the various distances and deflections you can promptly say where the tube is that causes the shadow.

Now hold the screen and circles so that the centres engage the anode-focus of the rays, and the two shadows will now not only be round instead of elliptical (as when out of a right angle), but the circumferences will be equidistant at all points, and the side-bars will register also as a single line. Shift the distance back and forth to test the effects on the shadows, and finally note that when the circles are centred correctly at twenty inches the two make a single shadow on the screen. When they do so on a plate and so appear in the negative they are *proof of the centred and right-angled relation of the plate at twenty inches from the anode source of rays.* When they deviate from a perfect register on the plate the direction and extent of the malposition of the tube is shown by the axis of the ellipse and the overlapping of the shadows of the circles. See Frontispiece.

In this description the author has considered only a single pair of circles of medium size. The operator who so wishes can as easily have several sizes, larger and smaller, and standardized for any desired distance. Three pairs would make a useful set. The proper measurements can be obtained from the Divergence Chart.

As a study of what is called *distortion* from the rays ten minutes actual observation of these circles, changing their apparent relation and situation as you turn their axis to the right or left, or up or down, will teach more of the causes of distortion, and how to avoid them, than will a year of the random work so common among beginners.

Having studied the shadows with the fluoroscope we are prepared to use the landmark in photography. After the plate, patient, and tube are all in position simply slip the device under the part on the plate so that the lower circle will outline the central field. The pressure or weight of the part will keep it in place. The upper circle then registers exactly above it in the path of the rays. To centre the landmark to correspond to the centre of the plate have a piece of stiff cardboard cut round to fit the circumference of the upper circle and pierced with a central hole. After centering the position-finder and before unscrewing the rod, slip this disk over the rod and then move the landmark until the upper circle engages the cardboard disk. Then remove the cardboard, unscrew the rod, leave the landmark in this position, carefully place the photographic plate under it, insert the part to be radiographed, and proceed with the exposure. While the standard of eight inches has been taken as an average distance *between* the rings, and is sufficient to admit most parts of ordinary patients, yet other pairs, both larger and smaller, may be kept on hand for all requirements of an extensive practice. The principle is the same in all cases. The circles will not interfere in any serious way with the diagnostic shadows on any larger plate, as they merely mark a ring around the central field. When not important to use them as proof of the procedure employed they can be set aside. Being extremely simple and made at small expense their value makes them quite an essential feature of X-ray equipment.

Proof of Distance of the Tube.—An operator doing a large amount of work will have on hand several pairs of circles standardized for different sizes of plates, and different exposing distances from the tube. The principle is exactly the same whether the landmark is large or small. The sample above described was constructed to merge the two rings in one shadow at twenty inches from the tube.

Shut one eye, and holding the landmark at arm's length with the smallest ring nearest the open eye, sight through the centre of the distant ring. Hold a yardstick also in front of the eye with the end resting at the side of the orbit. Now shift the distance of the landmark and note that all deviations in a perpendicular axis remove the two rings from a common register, but that in a perfect axis the eye will see but the shadow of a single ring, and the cross-bar supports will register as single lines when the yardstick shows that the largest ring is exactly twenty inches from the source of sight.

Move the landmark nearer, and note the change in the relative size of the two rings. Move it farther away, and note the altered size of the small ring. At all other distances except the standardized one of twenty inches, the rings make *two* shadows. The sharp-cut shadow in the radiograph will always be the one close to the film, the blurred and hazy shadow will always be the distant ring. When the circles are out of register in the radiograph and the distant ring is either larger or smaller than the ring against the film, measure the diameter of the shadow on the negative with a foot-rule; then turn to the author's divergence chart, and find the same diameter across the diverging red lines. This shows the exact distance required to alter the real diameter of the small ring of the landmark to the diameter imaged on the plate, and proves the distance of the exposure. Whether the tube was at twelve, sixteen, twenty-four, or thirty or more inches from the plate can thus be determined by the aid of the author's divergence chart.

So far as known this Distortion Landmark is entirely original with the author. To insure accuracy it must be correctly made, and not put together by rule of thumb. Proper accuracy in centering the circles will be secured by constructing the device upon a wooden cone of the required diameter at the base, and turned to a point to represent the focus of the rays. This is important.

No other device has hitherto been made which will perform the service of this landmark. It can be cheaply made. Make one and test its workings.

Special Landmarks.—For various purposes it is useful to mark the negative with devices of opaque bodies. A small piece of fuse-wire fixed to a part with adhesive plaster is a very common landmark employed in localizing foreign bodies. Numbers made of bent wire are laid upon one corner of the plate to identify it. Sometimes a stencil bearing the operator's name is used. The capital letters R and L are used to indicate right and left quadrants of the plate. Circles and bars of various sizes and thicknesses, perforated with vertical pin-holes, are also used as landmarks to test the angle of the exposure. A small coin is sometimes fastened to a part to identify the site of some transparent anatomical feature in the picture, as, for instance, the nipple, in examining the heart. Cross-wires are frequently used. The needs of different branches of work suggest to the operator such landmarks as will best serve his own purpose.

A simple and useful landmark is a small thin metal washer. When stuck on the skin with a bit of plaster to mark the spot on which the anode is focussed it leaves its shadow on the negative as a reference point. Before removing it from the skin make a more permanent mark with some stain applied in its open centre. Anything fixed in the negative that will indicate the centre of the focus, the upper right-hand quadrant of the plate, and the part exposed, if it is not self-evident in the picture, will aid in the interpretation of the negative. All practised workers attend to these points.

Note, however, that the negative will afford no legal proof that the anode-focus was actually in the axis perpendicular to one washer. The operator may state that the washer is at the foot of the axis, but in the absence of a second reference-point the fact cannot be proved. The author's Distortion Landmark is the only device so far offered the profession that embodies every proof desired.

CHAPTER XXII

THE AUTHOR'S POSITION-FINDER

An Accurate Means of Centering Plate, Patient, and Tube for Radiographs. A Study of Precision in Methods.

Next in the series of the author's aids to accuracy in X-ray work is a simple and effective Position-Finder. It performs a service similar to that of the "finder" on the camera. It *finds* the relating positions which the source of X-light, the axis of the rays, the photographic plate, and the centre of the diagnostic field, must bear to each other in order to produce a non-distorted shadow on the sensitive film. The same principle applies to the use of the fluoroscope. The author's gauge, landmark, and finder are three supplementing essentials which enable us to standardize three steps in skiagraphy *with the precision of mechanics.* With these instruments at hand the degree of X-radiance at any distance, the correct position of the diagnostic field, and the pictured evidence of accuracy, are scientifically demonstrated and removed from guesswork.

As shown by our divergence chart, every point on the circumference of a hemisphere in front of the anode is equidistant from the focus, and at right angles to the rays reaching it. Therefore, a hemispherical photographic film coinciding with any part of the radiant field would make a non-distorted picture throughout its entire extent, provided that the object radiographed conformed to the same shape. It is not so with a *flat* plate, but a glance at the chart also shows that any given ray in any part of the field will become a *perpendicular* and serve as the axis for a non-distorted shadow, if the surface of the plate is placed under it at right angles to it. While this fact has been generally recognized in theory many deviations from it occur in practice. The original position-finder was simply the casual glance of the operator, who put the tube where he thought was "about right." The next advance on this was the plumb-line. A plumb will drop from the point of a stick or the finger of the operator, and will indicate the perpendicular very closely, but it does not level the photographic plate at right angles to this perpendicular. It does not get any nearer than the wall of the tube to the actual focus-point on the platinum plate, and it is useless for lateral exposures and all others except the vertical. Within narrow limitations, however, it helps the operator to make a close guess. An *instrument of precision* is quite another matter, and the author offers such an instrument in his Position-Finder. See Plates No. 53, 54, 55, and 56.

The device is primarily a base and a straight rod with a small canal in it. A wooden base and a thin metal rod can constitute a scientific position-finder of the simplest character, but to serve a double purpose, as will be explained, we have made the base of brass about an eighth of an inch thick, eleven inches wide, and fourteen inches long. The front surface is marked with lines to indicate seven sizes of photographic plates, from 4 × 5 to 11 × 14. All sizes start from the lower right-hand corner of the base. At the exact centre of each plate the base contains a hole with a screw-thread in it. Near each hole is stamped in plain figures the size of plate which it *centres*. When any plate of any size is laid upon this base so that its side and end coincide with the same borders of the base, its centre will be exactly in the axis of the rays which the Position-Finder has previously located at right angles.

To study the principle of finding this axis make the following experiment: Excite a tube and stand in front of it with the fluoroscope as if for an examination. Now, with the left hand hold a steel knitting-needle in front of the screen with one end touching the fluoroscope and the other pointing to the tube. Make different lateral movements with the fluoroscope and note the length of shadow cast by the knitting-needle. Also hold the fluoroscope at right angles to the tube and slant the needle at different angles. This is excellent study of the *cause* of distortion. Also note that by watching the shadow and moving the needle so as to shorten it you finally reduce all its length to a mere round *spot*, and distorting obliquity has been eliminated in the line of the needle. *The needle is now exactly in the axis of the rays, and any picture taken under the same relation to the tube will show a non-distorted shadow within the exact field of the axis.*

Substitute for the needle a hollow tube, say a foot long, and with a lumen about the size of the knitting-needle. With the eye at one end sight it toward any gas or electric-light. It is like sighting a gun or bringing an object within the field of the telescope. In order to see the object the rays of light must pass through the narrow hole in the tube in the visual axis of the eye. Now do the same thing with an X-ray tube. Regulate the current so as to just redden and reveal

the focus-point on the anode. With the opposite eye closed sight through the tube and engage the focus. Also note how slight a deviation loses the focus. This teaches true *alignment*.

Next hold the same hollow tube in front of the fluoroscope and endeavor to engage the focus. Note that when it points at any other part of the anode the hollow rod casts a shadow of some length instead of a round spot, but when the focus is actually engaged the wall of the rod will cast the shadow of a small ring with a round transparent centre, proving that the rays pass through the lumen in a straight line to the fluoroscope. In making this last experiment use a tube-holder to support the hollow rod, and afterward remove the fluoroscope and with the ordinary eye look through the canal and observe that the red focus-spot on the anode is visible through it. Also observe the direction of the rod with relation to the plane of the anode. Without moving the tube, observe that you can swing the rod to *any other place in an arc of a circle* at any distance from the tube and *still engage the focus*. But note that even the slightest movement in a *horizontal* direction will throw the rod out of axis, so that the focus cannot be seen through it. These tests can be made with improvised material by any operator. *They demonstrate both the principle and the scientific accuracy of the author's Position-Finder.*

To use the instrument in practice screw the hollow rod into the hole which marks the centre of the plate which you desire to use. Connect the tube as you desire to use it, and put the base of the finder about where you would ordinarily put the photographic plate for the exposure. There are now three methods by which the *exact* position for the plate can be found.

1. Without exciting the tube shut one eye and sight down the line of the rod from the known focus-point of the anode. This off-hand method is a substitute for the plumb-line, is more accurate, is adapted to any position, and is correct enough for all ordinary work. It is not, however, the most *precise* method. Plate No. 53.

2. With the tube in action and just showing the red spot on the anode to locate the focus, sight through the finder from the back of the base and shift it till the red spot appears in the field. Let the base rest in this situation, which is the exact position for the plate. Or,

3. With the hollow rod pointing at right angles from the base, place the fluoroscope against the back directly over the hole into which the rod is screwed. Carefully shift the finder till the lumen of the tube is seen as a round transparent spot, indicating that the rays have passed directly through the canal of the metal rod. This is the precise centre of the given field of X-rays. Plate No. 55.

After using whichever one of the above methods is most convenient in a given case, simply unscrew the rod and lay it aside. The base remains in the right position for the radiograph and has secured both elements of accuracy, viz.: the *perpendicular* and the *horizontal*, which a plumb-line does not do. Throughout the process the tube remains unchanged. As shifting a tube to suit a fixed field for the plate is much more difficult than to find a plate-field for a fixed tube, the advantage of this Position-Finder is manifest. But it has other advantages.

Now bring in a photographic plate. Place it in position upon the base of the finder. The simple act of laying it on the finder at once *automatically squares, levels, and centres it.* It only remains to place the patient on the plate and the part is automatically brought into correct relation with the tube, and the usual tedious process of adjusting the tube after the patient is placed is entirely eliminated.

If a second exposure is required the second plate can be next automatically centred in exactly the same field occupied by the first. Before placing the part over the plate mark the skin with both the centre and circumference of the diagnostic field; lay the marked centre on the centre also marked on the envelope containing the photographic plate, and you at once secure the best relation of the diagnostic field to eliminate distortion without any other measurements, adjustments, or apparatus of any kind. The four centres are lined in one perpendicular axis.

To mark the centre on the envelope simply draw with a ruler and pencil two cross diagonal lines from the opposite corners of the plate. The intersection of this X will correspond with the centre of the film and the exact axis of the central rays, for it will be the position denoted by the rod of the Finder which locates the axis. If special marking of the diagnostic field on the negative is desired simply fasten a ring of fine copper-wire on the skin of the patient with strips of adhesive plaster, and when the negative is finished it will be marked with the same ring.

It is also obvious that *this method of centering the diagnostic field always indicates to the operator the essential part of the negative to study for diagnosis.* This is especially useful when a large negative is made. In addition to rendering the above services the heavy and rigid metallic base of the Position-Finder gives a firm unbending support to a glass plate, preventing breakage under a heavy body. It also *backs* the plate with a dense protective which is opaque both to direct and secondary X-rays; thus sharpening defini-

PLATE 53.—Author's Position Finder. Ready method of centring plate with focus of tube, as taught in the text. Operator is sighting down anode and along rod to base. The lines on the base show different sizes of photographic plates, each of which has a centred hole for the rod. Shift the base with the hands till the focus is sighted, then remove the rod and lay the plate on the base film side up. Then place the part to be radiographed on the plate with its marked centre on the centre of the light-proof wrappers. See text for full directions.

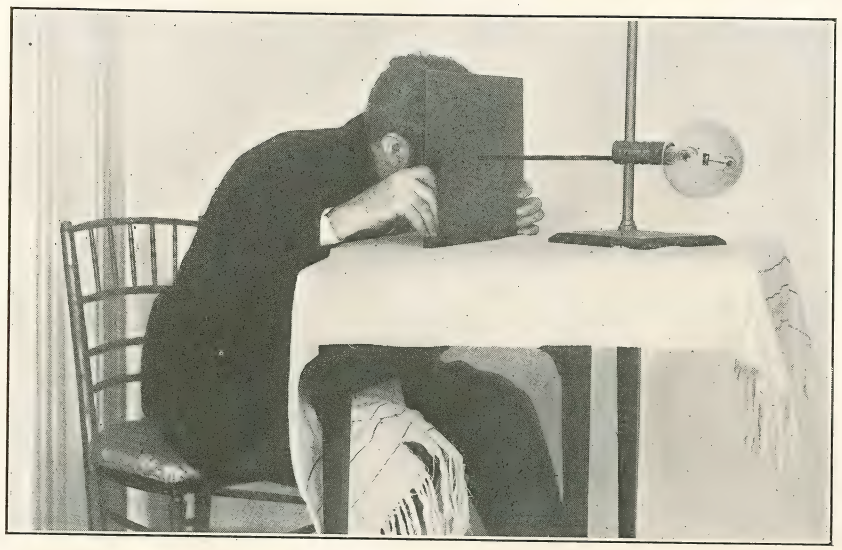


PLATE 54.—Author's Position Finder. Sighting through channel of rod to find axis of rays from the tube-focus. See text for full description of method.

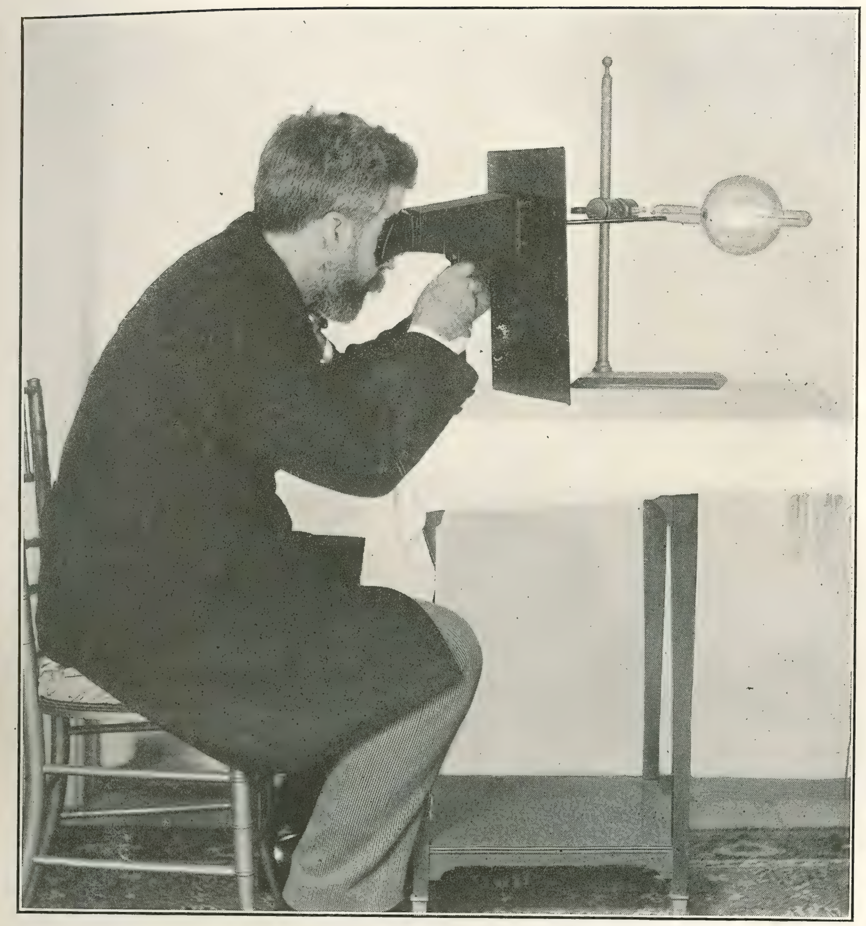


PLATE 55.—Author's Position Finder. Sighting shadow of rod with fluoroscope as described in text. The three Instruction Plates of this instrument sufficiently teach how to secure with its aid an exact central field in the axis of the X-rays, and, when found, to locate the part in this position for radiography. It will be seen also that the flat metal base makes a secure support for a glass-plate, placed, for instance, under a patient who is on a canvas stretcher. It prevents breakage, absorbs the rays, and is a valuable device.

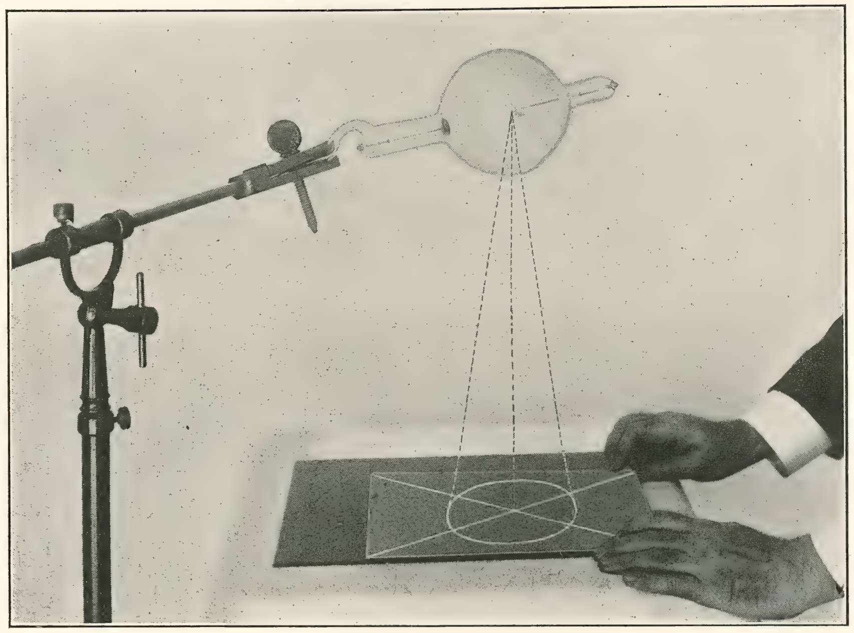


PLATE 56.—Diagnostic Field and Axis of Rays as shown by Author's Position Finder and Landmark. Having sighted the rod of the Position Finder and secured the focus remove the rod. Draw two diagonal lines across the light-proof envelope of the plate from corner to corner and their intersection marks the centre of the film. The vertical dotted line occupies the place of the rod and is the axis of the rays, carrying down shadows to the centre without divergence or distortion. As the rays form a cone they have a circular field on the film, which is shown by the ring. The slant of the side rays is shown by the diverging lines. With these aids to accuracy all errors of position area voidable. See study in divergence and distortion in the text.

tion, preventing blurring, and shortening the time of exposure, as is explained in another chapter.

In accurate radiography certain firm supports are needed for the various parts of the body. These are tables, stands, blocks of wood, frames, etc., such as ingenious operators have devised for their special use. The tube-holder is sometimes separate, and sometimes attached to these tables. The slightest move of either the table or the Crookes tube displaces the focus, and an *uncentred* negative results. It is the author's design to have a bent-arm tube-holder fixed permanently to one side of the base of the Position-Finder. The device then becomes connected with the tube. When the tube is once focussed it remains so, and the base to which it is fixed can be moved anywhere and shifted to any position adapted to the patient without altering the correct relation of the plate. Exposure after exposure can be made with accuracy and without delay, with no subsequent repetition of sighting the focus. The base can be clamped upon any table, stand, or frame, and thus simplify matters by affording a permanent adjustment. Nothing has been said here about the distance of the tube from the plate. This is fully considered in another place.

In discussing the wrong interpretation frequently made by surgeons of the "skiagraphic testimony regarding Colles's fracture," Thomas aptly remarks that *you cannot see through a key-hole unless your eye is in the right place.* X-rays will not show clearly a line of fracture unless the anode is perpendicular over the line of fracture, with the bones so placed that the fracture has a chance to show. He remarks that if special attention were given by surgeons to the position of the anode while making radiographs there would be less criticism of the results. Stress is laid upon the importance of "using a plumb-line in placing the tube," and a number of somewhat complex suggestions have been given to assist the operator in getting the tube fixed properly *over the part.* It seems to me that a much simpler way is offered by my position-finder. This entirely ignores all processes which first prepare the part for exposure and then make efforts to fix the tube directly over it. It simply, and at once, automatically centres the axes of the rays with the centre of the photographic plate, and over this marked centre the part can be laid upon the envelope with exact reference to the cross lines. It is only necessary to lay the line of fracture on the line marked on the envelope of the plate without regard to the tube. In other words, it is easier to adjust a part *under* a tube than to adjust a tube *over* a part. The Position-Finder makes this process almost instantaneous with a little practice.

CHAPTER XXIII

AUTHOR'S ONE-MINUTE LOCALIZER AND EXAMINING FRAME

ITS THREE USES. DIRECTIONS FOR FLUOROSCOPIC WORK. LOCALIZING TECHNICS. HOW TO READILY LOCATE A BULLET IN THE CRANIUM.

Localization may be desired for several other reasons than the removal of a foreign body. There are three phases to the requirements of localization. It may be (1) general, (2) approximate, or (3) exact.

To obtain a *general idea* of the presence and situation of the foreign body, fracture, or other lesion correct inspection with the fluoroscope or a centred radiograph suffices.

To obtain *approximate localization*, especially as to depth, either the fluoroscope or the simple radiograph may suffice, but closer observation, some surface markings, and the relation of landmarks (or a stereoscopic view), is essential. When surgeons lose their present dread of approaching those finer fields of X-ray work in which the enthusiast-expert revels with delight the stereoscope will be the ideal means of observation for this purpose. Probably the details of stereoscopic X-ray work will gradually appear easier to the rank and file of the profession as average technic reaches a higher level and fewer men are content to risk their reputation by simply "slapping a plate under the part, putting a tube over it, and letting it go at that."

Exact localization requires more than the unaided fluoroscope or simple plane radiograph. It usually requires some mathematical computation to arrive at "depth," and all processes so far described with any form of localizer call for *two* exposures, *two* radiographs, or *two* observations of some kind in directions as nearly at right angles as possible with certain apparatus, and, with cross-thread methods, a shifting of the position of the tube. While an expert constantly doing this work can secure a result so quickly that the bystander thinks it is easy, yet when the average operator whose needs for the method are but occasional thinks of doing the same thing himself, it takes on difficulties that loom up large to deter. Simple things become unhandy when the hand is out of practice.

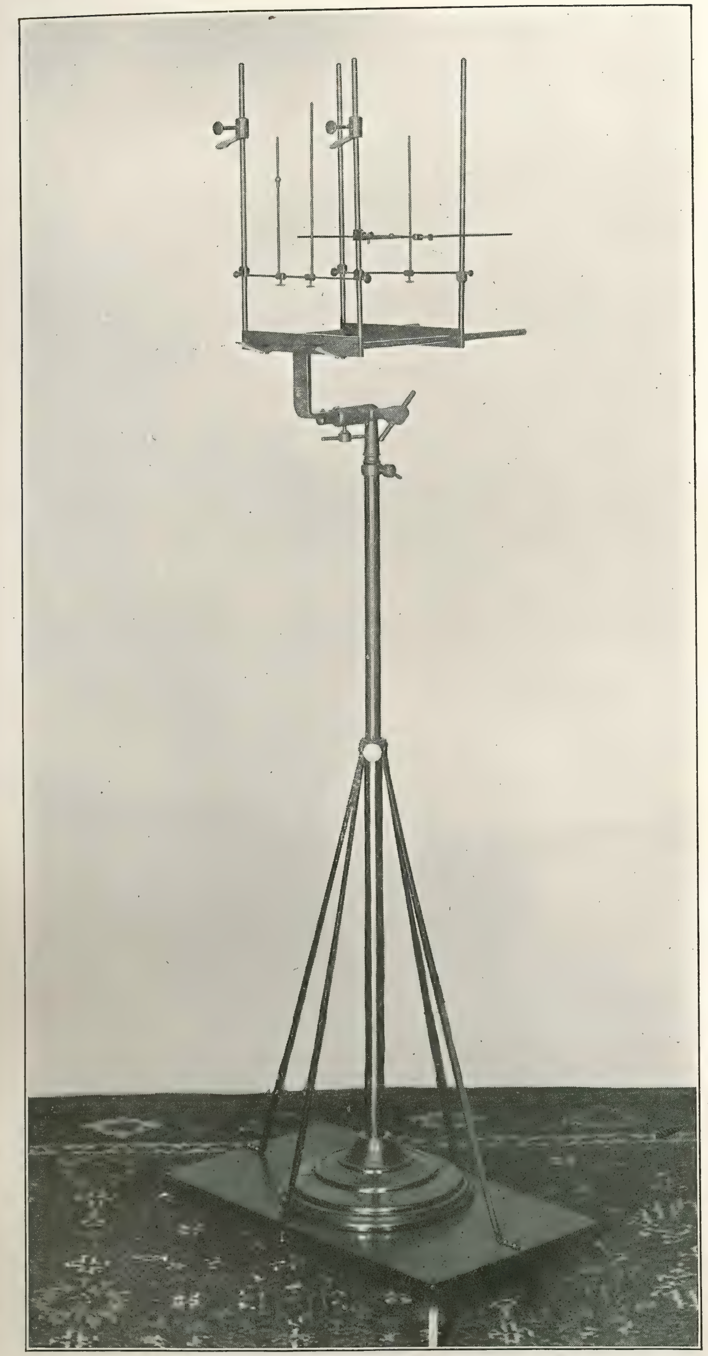


PLATE 58.—Author's Examining Frame and One-Minute Localizer.

See following page for description.

Author's Examining Frame and One-Minute Localizer.

This instruction plate illustrates the manner of setting up the Author's Examining Frame with clamps on front posts for holding the screen or fluoroscope, and the rods and markers in position for localization. The frame can be taken apart at any or all of these joints, and the examining frame lifts from the standard for use on a table-top when desired.

The upper pair of clamps hold the fluoroscope on the frame and can be moved up or down as desired. The bottom of the screen clamps in two foot-rests. A second pair of lower clamps like the upper ones is furnished, but are not shown in the photograph. They hold either an open screen or the regular fluoroscope.

The front and back horizontal rods, together with the front and back vertical rods, constitute the *markers* of the *axis* of the *rays* when they are adjusted in the line between the examiner's eye, the screen, and the focus of the tube. The intersection of each lateral with each vertical rod makes a right angle, and when the shadow of the part examined is placed in the two sides of the square at the point of intersection it is exactly in the *X-ray field of non-divergence* and *non-distortion*. The rays passing through this field are rectilinear at right-angles to the visual axis or to the photographic plate.

The *depthing* rod is adjustable antero-posteriorly on the rod, which is parallel to the axis of the rays between the front and back of the frame. On the depthing rod are the adjustable pin and ball which are used in localization as taught in the text.

A vertical rod bearing a sliding ball is carried by the front "marker." When slipped any distance to the left of the vertical rod of the marker it serves as a guide to the vertical line of any shadow over it at any level above the horizontal rod of the marker. The ball or pin on the depthing rod is guided to exactly this vertical line (over a bullet, for instance,) by sliding the depthing rod backward. That at once localizes the foreign body without any figuring or plotting out a diagram on paper, or measurements of any kind.

For use as a localizer the depthing rod is placed on a front side-post. It is removed when the frame is used for examining only. Notches one inch apart in the base aid the eye in off-hand estimates of distance. Set-screws permit all rods to be shifted to any and all positions needed in practice.

To adjust to height raise or lower the main post, which telescopes into the standard. To turn frame horizontally loosen the lower set-screw at head of post. To turn in antero-posterior arc loosen the set-screw just above. To turn in a lateral arc loosen the set-screw under the head at left of post. To adjust frame to width of part slide the rear half forward or backward as needed. To level the cross-rod markers loosen the set-screws at each end and slide to suit. Adjust the vertical rods in the same way. It is all done quickly with the briefest practice and has no complications. The *depthing rod*, the salient and original feature of this device, does not show well in the plate, owing to the position of the camera when photographed. It is the upper horizontal rod running half way across the figure toward the left post. It is adjusted by a set-screw to any position on the upper rod seen running back from the front right-hand post to beyond the rear post. To use the frame on a table simply lift it from the standard and lay it on the table.

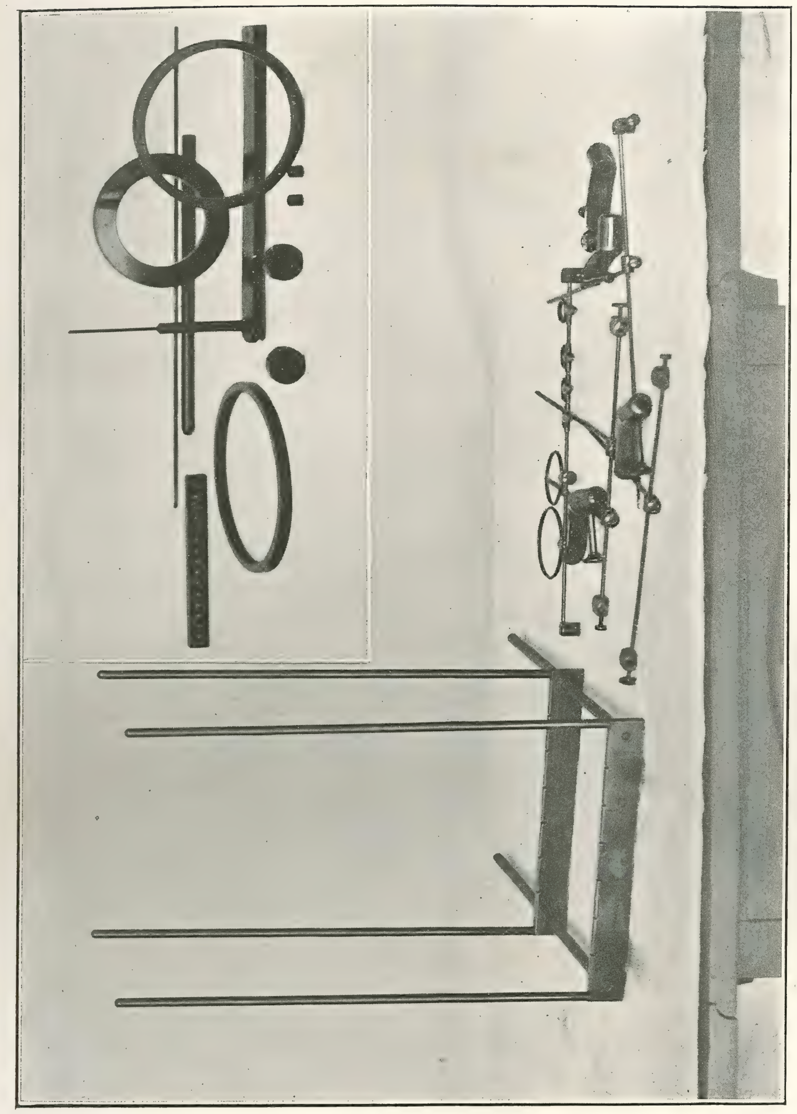


Plate 59.—Author's Examining Frame and Localizer and various Landmarks Useful in Radiography. This plate illustrates how the frame may be taken apart for ready adjustments of any markers selected. The rods and markers lie on the table at the right of the stripped posts. In the upper corner are separate landmarks. Magnify this plate with a fine reading-glass and the details of the pieces will be clearer.

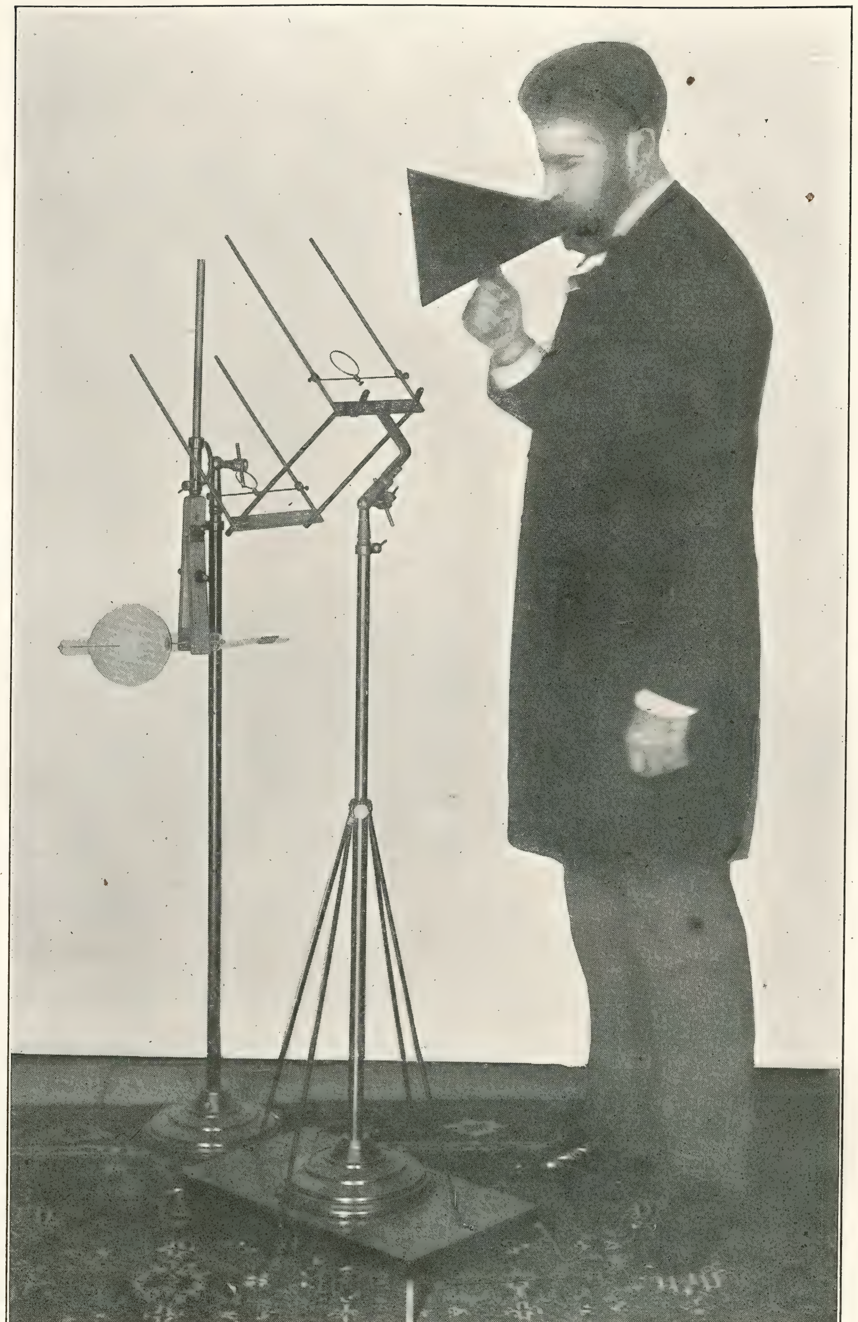


PLATE 60.—This instruction plate shows Author's Frame and Localizer with a pair of rings substituted for rod markers to define a small field for examination. Also shows how frame can be tilted to any angle to engage axis of rays. Press the part to be examined close against ring on front and it will be in path of vertical rays.

Therefore a *direct localizer* which will work at sight with a single technic in but one plane comes near to filling a long-felt want in the profession. Such a device has not yet been adapted to the finer work on the eye so well accomplished by Davidson's method, but it can be used in many parts of the body, and, whenever it can be used at all, its advantages commend it to the surgeon. Such an instrument will now be described.

The Examining-Frame.—This practical little instrument, devised by the author in May, 1901, will be found of great service in many examinations with the fluoroscope, and has three uses:

1. It affords a practically instantaneous means of squaring the fluoroscope and tissues with the axis of the rays at any level and at a correct right angle. It establishes a correct field for the examination of a part, and a means of retaining it during all necessary movements of the examination. *Within this field, the anatomical relations are shown without distortion.* As an *examining-frame* it finds and fixes the field of observation and enables the operator to avoid divergence. The simplicity with which it does this must be seen to be appreciated. It also supports the fluoroscope by clamps.

2. As a *localizer* of a foreign body in parts accessible to the fluoroscope it does its work in about one minute, with but one posture of the part. It eliminates mathematics, cross-threads, and the radiograph from the localizing process. Both the level and *depth* of the object sought are shown with a single posture of the part, and the simplicity of the entire process commends it to both military and private practice.

3. When in position between the tube and tissues, and connected by a wire or chain to a gas-fixture or water-pipe in the office, it grounds electrostatic effects without any further complication.

The utility of the instrument in localization coincides with the capacity of the fluoroscope. It is especially convenient for the extremities and general work relating to parts of the body which the operator can manipulate as required in fluoroscopic examinations. Fine ophthalmic work so brilliantly accomplished with another localizer is beyond the scope of the author's apparatus, which is only designed as a simple and ready means of doing work that demands quickness and simplicity, leaving finer work to finer apparatus.

The instrument is intended for use upon (1) a standard, or (2) upon an examining-table. For the extremities and certain other parts a standard is especially convenient for the operator. Two hinges working at right angles permit movement of the frame through nearly a complete circle, either from side to side or antero-posteriorly. The telescoping rod of the standard permits it to be shifted to any height to suit the operator, who may sit or stand, as he prefers. A revolving post below the head permits a complete horizontal revolution of the frame. Set-screws adjust the parts as desired. The essential frame consists of two pairs of similar upright brass posts and cross pieces, adjustable to different distances from each other. A set of "markers" adjustable to all desired locations, and clamps to hold the fluoroscope, complete the device. The construction is too simple to call for further description beyond that shown by the photographs. (Plate No. 58.)

Directions for Use on a Standard.—1. Set the frame in front of the Crookes tube in the place that would be occupied by the subject in an ordinary fluoroscopic examination.

2. Close up the base and slide the markers together, so that they register as *one*, and then slide back the rear frame far enough to admit the part to be examined.

3. Level the frame to the height of the operator's eye.

4. With one eye closed, sight the focus of the anode and engage it in line with the *intersection of the markers.*

5. Clamp the fluoroscope on the front of the frame and insert the part to be examined.

So simple are these steps that they require no more than half a minute. We now have a definite field within which the axis of the rays traverses the tissues at right angles. The frame keeps this correct field constant before the eyes, with the rays perpendicular to the fixed plane of the fluoroscope, while the part to be examined may be shifted in the frame back and forth, up and down, and turned in all desired directions. As each area of the tissues is successively brought into the field defined by the markers the whole of an extremity can be examined with all distortion eliminated. Both hands of the examiner are free, as either a mounted screen or the fluoroscope is held securely in place. No particular preliminary posing of the tube is required. As all parts of the frame are both separately and collectively adjustable at any height, angle, or position, it can be sighted toward the focus of a tube situated anywhere, just as a rifle can be sighted at any target. *This independence of an exact position for the tube is a great convenience to the operator.* The actual setting of the adjustments of the markers in the frame is almost as simple as setting the hands of a watch, and can be almost as quickly done. Of course an object-lesson demonstrates this facility far better than can be told in print.

Directions for Use on an Examining-Table.—With the patient recumbent, examinations require that the frame be lifted from the

PLATE 61.—This instruction plate shows the Author's Examining Frame with its adjustable wooden floor used to level a part and support it during examination or localization. Turning the long spiral screws raises and lowers the upper shelf on which the part rests. Note the exact register of the two vertical guides in the axis of the rays. The central radiation coincides with the point where the horizontal and vertical guides intersect and the fracture, lesion, or bullet to be examined or located is seen without distortion when brought into this exact field. The plate teaches its technic at sight.

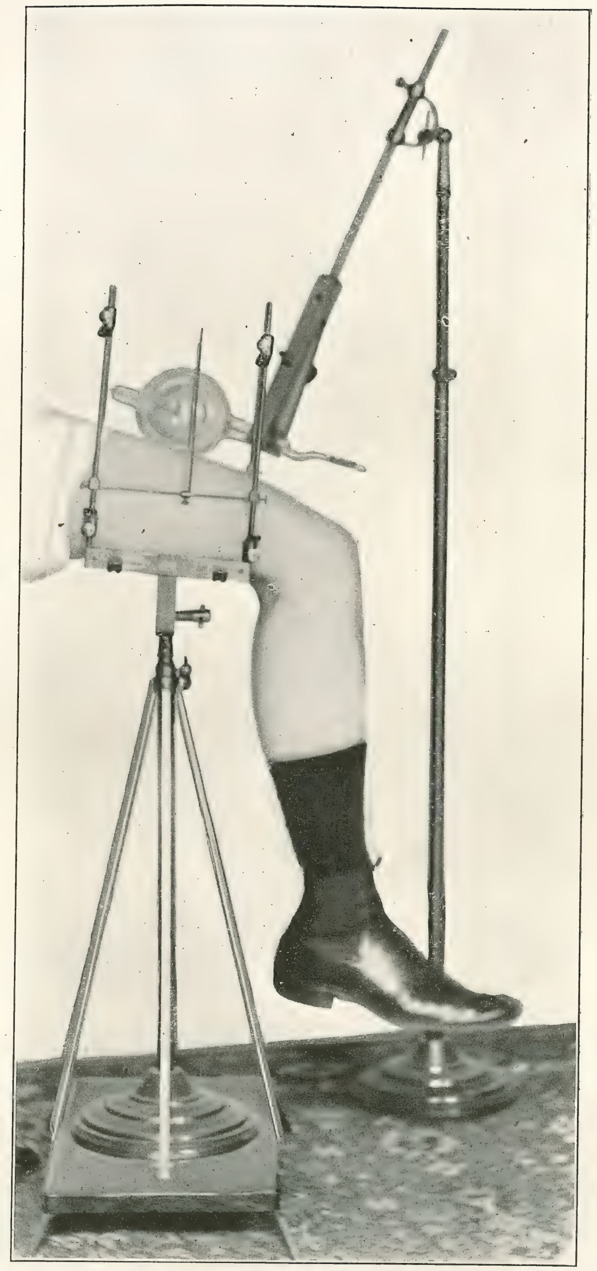


PLATE 62.—Author's Examining Frame and One-Minute Localizer, with middle of thigh in position for either simple examination or the simultaneous location of any lesion or foreign body. With the frame and part in this position sit in front of the frame, clamp the fluoroscope on the posts and inspect in the usual manner. Note that the frame holds the radial axis fixed and any part of the leg from the hip to the heel can be rapidly passed through the field of the non-distorted rays for successive examination. No other equally simple method exists.

PLATE 63.—This instruction plate shows the Author's Examining Frame turned to side position to accommodate the thigh, or any part of the leg (or body), with the patient erect. As the frame has a universal series of joints it can be adapted to all positions in a moment. Examinations are a mere question of levelling the line of sight—swinging the frame into the axis of the tube in any desired situation—and then passing the part in view before the fluorescing screen in the field that is secured correctly by the markers. Study this important series of plates as a whole and in connection with the text and the general uses of the apparatus will be apparent.

PLATE 64.—Author's One-Minute Localizer locating a bullet in the forearm with a single posturing of patient. Level the markers and tube as taught in the text, press the part on the front marker and screen, shift arm till bullet engages in angle of markers, then—(See next plate for second step).

standard and laid flat on the surface of the table. The adjustability of position formerly furnished by the standard and its hinged joints must now be supplied in one of three other ways:

1. A movable table-top, which can be tilted or partly revolved on a pivot will enable us to accommodate the frame to the focus of a tube in an ordinary independent tube-holder, in which the tube remains fixed where originally placed.

2. With the top of the table and frame both stationary, the focus of the tube may be accommodated to the examination by the tube-carrier, consisting of a bar attached to the opposite side of the table so as to permit the tube to slide along it, as in the Davidson apparatus.

3. An independent adjustable tube-carrier of great general utility for all examinations will be particularly useful in the present case and may be made as follows: Make a solid rectangular frame six feet high and two feet wide, grooved along inside upright posts to permit a small secondary frame to glide up and down within the large frame, as a window slides in its sash. Within the small frame construct a cross-bar tube-carrier. Have the main frame stand on legs or a base which will retain it securely wherever it is placed. Arrange a counterpoise weight which will suspend the frame holding the tube at any point desired. Arrange a set of pulleys and cords above and below the centre of the small frame, running to the top and bottom of the large frame so that sitting in his chair in front of the patient the operator can pull the tube-carrier up or down to any level required. Arrange a set of side cords which will pull the tube laterally across the horizontal-bar within the small frame. With this device for holding the tube the operator can then, without leaving his chair or taking his eyes from the fluoroscope, make the final small adjustments of the tube which will be required to bring the anode focus in line with the field markers of the examining-frame. When this is done, the method of making the examination is the same as before. Insert the part and fluoroscope and proceed.

Directions for Use as a Localizer.—Arrange the frame either on the standard or on a table, precisely as for any fluoroscopic examination, with the focus of the tube and the markers registering in line. Insert the wooden floor. Add the *depthing*-rod to the front right-hand post near the top. Insert the part containing the bullet. Lower the depthing-rod to contact with the surface of the part, and shift it to the extreme front of the frame against the fluoroscope.

With the tube lighted up and the fluoroscope finding the general situation of the bullet, quickly move the part till the bullet *engages the shadow of the vertical marking rods.* By means of the spiral screws, raise or lower the floor till the bullet reaches the *level* of the *horizontal marking rods*. It requires but an instant to thus engage it *at the point of intersection of the markers*, provided it is in a part which permits ready movement. In more difficult parts it will take a little more time.

Next turn the frame laterally on its pivot till the shadow of the bullet travels along the horizontal marker to a second upright rod about two inches to the left. Shift the depthing-rod *straight backward on its cross-bar*, till the shadow of its ball travels over to the marker pointing directly up from the shadow of the bullet. This completes the entire localization. *The bullet is as far in from the surface as the ball on the depthing-rod has been moved back from the front.*

The line of the *horizontal marker* gives the level of the bullet above the floor on which the part rests. Remove the fluoroscope, and with a dermal pencil mark a line on the skin parallel with these front and back horizontal markers, to record the cross-section wherein the bullet lies.

But how far *in* from the surface is the bullet? This is exactly indicated by the ball or pin on the *depthing*-rod. Its ball is exactly over the bullet in the exact line of the cross-section, and it has *found the depth* of the bullet without turning the part over or changing its posture in the slightest. In this respect the apparatus is unique.

The depthing-rod is provided with both a small ball and a short pin. The operator can use as an indicator whichever he prefers in a given case. Pressure of the pin on the tissues will make an accurate preliminary marking, which can be made permanent by nitrate of silver.

The localizer will perform its work in almost any position in which a part can be placed in it, and the operator may choose that which is most convenient. It is best adapted to the *cranium* and extremities. If a round bullet or object is localized very exactly, the ball of the depthing-rod will indicate the perpendicular of the *anterior surface* of the bullet. *The body of the bullet will lie behind the plane of this perpendicular.* If an elongated object is localized, the frame can be shifted to show the longest axis of pin, needle, bullet, or fragment of bone, and both ends and the connecting line between them can be mapped out automatically by the depthing-rod and the level finders. *No calculation or figuring at any time is required.*

In practice to become familiar with the device the beginner may bury small pieces of metal in irregular blocks of wood, odd shaped masses of bread, meat, or any convenient material. After making the shadow travel to the side post out of the direct axis of the rays,

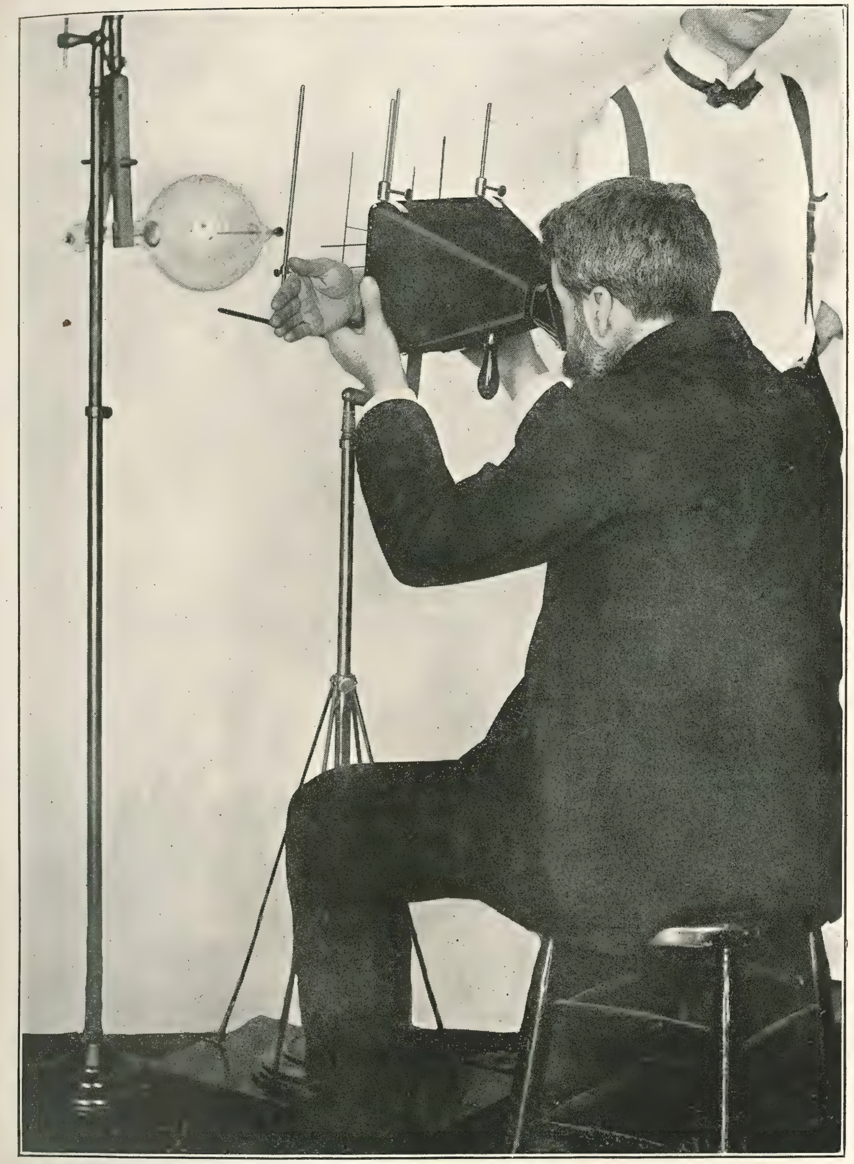


PLATE 65.—Author's One-Minute Localizer. Second Step. With all parts held as before simply give the entire frame, with screen and arm, a slight lateral turn to either right or left. Stop when the bullet has travelled over to the vertical guide. With the right hand slide the *depthing rod* straight back on its guiding rod till its marking pin is exactly over the shadow of the bullet on the vertical guide. The bullet is located by this simple method without any divergence or distortion whatever and in a single moment. Hold the part still in the frame, unclamp the fluoroscope, mark the point of the front marker on the skin and mark the skin where the pin of the depthing rod touches it. When the two cross sections are thus marked the surgeon will find the bullet at the intersecting point without deviation. Study these plates in connection with the descriptive text.

PLATE 66.—As an informal study in approximate localization observe that the fragment of needle in this picture has a sharp and apparently unmagnified shadow. It is therefore nearer the film than the bone.

PLATE 67.—Arrow points to bullet located in skull underneath pons. Verified by operation and removal of bullet.

and shifting the depthing-rod, the operator may *prove* the accuracy of the adjustment by returning the frame to its original position; and if the ball on the depthing-rod is in line with the upright markers at the same time that the bullet is in line between the same markers on its lower level, it proves the result. The real facility of the *depthing-rod*, which is an absolutely unique device, can hardly be made plain till the student tries it himself. It works so simply that a child can understand it by a glance at the apparatus.

How to Readily Locate a Bullet in the Cranium.—By some of the methods described the localization of a bullet in the head may be considered so difficult that attention should be here called to the practical simplicity of the author's "One-Minute" Localizer in this particular emergency. It is doubtful if any other method so far known can compare with it in both accuracy and the quickness with which it can be done.

A lead bullet can be plainly seen in the cranium with the fluoroscope and any efficient modern apparatus. No radiograph is required. Proceed as follows: First view the head through the fluoroscope to see what position gives the best view of the bullet. Then shave the hair from the spot where the shadow falls on the screen. Next have the head held in the frame so that the shaved spot will rest against the front markers.

Engage the shadow of the bullet in the exact angle of the markers as taught. Then turn the frame and head together (as taught in the directions for localizing) and slide back the depthing marker till it indicates the *depth* of the bullet. Then shave the hair from the spot and again set the depthing-rod which was moved aside for the shaving. The exact localization is now complete. It has required scarcely more than a minute. To mark the scalp is the next need.

Cut two small round pieces of adhesive plaster one-fourth inch in diameter. Stick one on the scalp exactly under the marker of the depthing-rod. Remove the fluoroscope from the frame and stick the second piece of plaster on the scalp exactly in the marked angle of the rods in which the shadow was engaged. The bullet lies at the intersection of the two cross-lines marked.

Without any further "computation" or measurement the surgeon can readily judge how he will enter the skull to remove the bullet if an operation is decided on, or, having found where the bullet is, a decision to leave it *in situ* will be guided by known facts instead of guesswork. But in a very simple way exact measurements can be taken as follows:

After removing the patient and the fluoroscope (but with the markers and depthing-rod still left in position) lay one of the extra rods belonging to the set furnished with the frame across the markers so that it rest in the angle of intersection. Then either with calipers or a rule, or in any convenient way, measure the distance from the rod up to the ball on the depthing-rod. This gives the depth of the bullet below the scalp in inches and fractions. Then measure from the depthing-ball to the front marker, and this shows in inches the distance from the scalp to the bullet in the same direction. These measurements equal two sides of the square, and the other two sides can be measured in the same way if desired to complete the record. The actual simplicity of the only part of the technic that is really essential to the surgeon can perhaps not be fully realized from this word-teaching, but get out the frame and try it in practice, and the result will show its ease and readiness.

CHAPTER XXIV

METHODS OF LOCALIZATION

Studies in Principles and Technics. Triangulation. The Fluorometer. Localization without Plumb-lines or Threads. Ophthalmic Localization. Davidson's Thread Device. The Remy Localizer. Punktograph. Shenton's Method. An Emergency Case.

It is quite certain that the average surgical mind is more or less repelled by the formula and diagrams with which localization of foreign bodies or lesions in the tissues have often been presented in X-ray literature. And when, added to the difficulties of following the directions of a narrative writer, we find so many mistakes made in simple technics, it is small wonder that a clear mastery of the process has not been attempted by one surgeon in a hundred. Yet the matter is important when needed, and can be simplified. This we shall undertake to do in such a way that every student of this course can successfully apply a localization method to any case he may have in hand.

Back in 1896 the teachings were geometrical. The theory was one of simple "triangulation." Many jumped to the conclusion that two radiographs taken at right angles to each other, or two cross-sections observed with the fluoroscope and marked on the skin, would locate the object, and that the needle or bullet would be found by cutting down to the intersection of the two lines. It would be so found if the tube was in line, but unfortunately too many overlooked that simplest law of the projection of shadows from a point of light and failed to cut in the same direction that the light had been projected in. They worked out of the axis of the rays, and hence hundreds of errors were made and X-rays were called inaccurate, when the truth is that a straight line cannot deviate from accuracy. All it needs is to be aimed in the right direction. Then it will surely hit the mark. Working without regard to the line of the focus of rays, men sought to figure out the error of alignment and finally locate the bullet by a mathematical problem in triangulation. This insured scientific correctness, but was hard for physicians rusty on their algebra.

The technic was taught with scores of variations. For a needle in the hand cover half a plate with opaque lead. Place the hand on the other half, set the tube vertically over it, and make an exposure. Then shift the lead to the exposed half of the plate, put the hand on the fresh half, move the tube to an angle at one side and make a second picture. Then figure the angle of deflection. Many hastened to suggest improvements to this crude process. Merril taught:

"Place the plate on the table with the part containing the bullet over it. On the skin mark two sides of the plate. Place the tube over the side (not the centre) of the plate. Make the exposure. Drop a line from tube to skin and mark skin. Then remove patient, continue line to plate, and mark it with a pin prick on the film. Develop this negative.

"Place a second plate on the table with the part on it as before. Shift the tube a couple of inches. Drop plumb-line, measure and mark as before. Develop. Make prints. Lay the two prints with their reference edges together. Prick pin-holes through centre of bullet-shadow and plumb-line from tube. Take out the under print, and on its back there are now four pin-holes. These bear the same relation to each other that the shadows of the bullet and the lines of the rays in the two exposures have on the plane of the plate. Join these holes by two intersecting lines, and the point of their intersection will be perpendicularly below the plane of the bullet. Plot the triangles and figure out the result. To apply result to patient plot the measurements on the skin."

Two amplifications of this method were taught by the same author. The elaborate algebraic tables and calculations submitted by a score of teachers of early triangulation methods are here omitted. The mathematician does not need them, and others could not use them if they were cited. The simplest technic possible for working out the same principle without a localizing instrument is as follows: Centre the tube at twenty inches over the plate. Place the patient on the plate so that the bullet is over the centre of the plate. Slip a sheet of lead on the left half of the plate. Shift the tube three inches to the left of the centre and make the first exposure. Then shift tube three inches to right of centre, cover right half of plate with the lead, and make a second exposure with the patient unchanged. Then develop the plate. Then measure on the plate the distance between the centres of the right and left shadows of the bullet. Let us say it proves to be two inches. Multiply this by the distance of the tube (twenty inches). The product is forty. Also add the two inches between the shadows to the six inches the tube was moved parallel with the plate. The result is eight. Divide forty by eight and the bullet

is the resulting five inches from the plate in a vertical line above the centre. When stated in algebraic formula with unknown measurements it looks complicated, and to make its real simplicity appear we have assumed distances in plain figures instead of $xy = \frac{AB \times CD}{Mn + AB}$

For fine measurements a centimetre or millimetre scale would be used, but we illustrate it in the more familiar inches in order to make it clearer to the beginner. The bullet will not be in a vertical line above the centre unless the technic is carried out exactly as here taught.

As some opprobrium has been cast upon X-rays and localizers in respect to needles which surgeons have failed to find in the place where they ought to be, after a careless X-ray observation by some inaccurate method, Scott makes the following suggestion: "Do not subject the patient to any delayed search. With the fluoroscope observe the needle again, and at the same time place the scalpel in the wound and you will instantly see the relation the knife bears to the foreign body. The further incision can then be definitely made."

Military Practice.—Of localization in the Spanish-American War of 1898 the special surgical detail of the Government reports:

"One thing this war has taught us is that the *probe* in all its forms *has gone out of use.* No more searching blindly in a man's body for the bullet; no more danger of blood poisoning from the introduction into the wound of instruments of search. The fluoroscope tells us instantly where the projectile has imbedded itself, and we have only to cut it out as if it were there before our eyes. *The ingenious electric probe and all similar devices have seen their day.* In all future battles experts in skiagraphy will be attached of necessity to the medical corps, and the work of the surgeons will be materially assisted by their precise indications. We took out bullets by the pint on board the Relief ship, and almost without exception they were located by the X-rays. It was all done in a few moments; five seconds for a wound in the hand; thirty seconds for a wound in the foot; not over ten or fifteen minutes for a wound through the thick pelvis. The patient is stretched out on a table, the X-ray tube adjusted over the wound, the plate put under the limb or part where the wound is, and the thing is done. The plates are developed almost immediately; in many cases we save *hours of vain searching;* not infrequently we save the soldier's life."

The Fluorometer.—The following description of this instrument and the photographs from which the cuts were made were prepared especially for this book by the courtesy of the Rochester Fluorometer Company. The most recent form of the apparatus is presented.

"The accompanying illustration and diagrams show the practical application of the simplified form of the Dennis Fluorometer in its use in utilizing the Roentgen rays for surgical and medico-legal purposes.

"As shown in the illustrations the appliance consists of a suitable frame work, a thin horizontal metallic-bar, two adjustable thin vertical bars with movable sights or pins, a metallic screen or grating with appropriate standard for maintaining it in position, and to serve as a plate-holder when the desired position is obtained.

"In the present state of advancement of the art all X-ray operators are familiar with the distortions in the shadow caused by the divergence of the X-rays. The function of the Dennis Fluorometer is to eliminate this distortion and to produce accurate results, both on the fluoroscopic screen and the sensitive plate (as shown in plate 71). In other words, to provide the surgeon or medico-legal expert with data upon which to base positive and unerring diagnosis. It is so constructed as to apply equally to all parts of the human anatomy.

"For the purposes of this description a case of a bullet in the human wrist is selected as shown in the plate. The wrist is placed with the palm of the hand downward between the two vertical bars of the instrument. Observing now with the fluoroscope, the tube is so adjusted that the two vertical bars show a single shadow on the fluoroscopic screen. The limb is then moved until the shadow of the bullet coincides with the single shadow of the vertical bars. It will be seen at once that if the limb should be amputated at the point indicated by the two vertical bars, the bullet will be encountered on this cross-section, and its position vertically above the horizontal-bar will be indicated to the observer on the fluoroscope by the meshes on the metallic screen. See Plate No. 72.

"Just here two movable pins or sights on the arms of the Fluorometer appliance come into use. These pins are placed equidistant from the base of the Fluorometer (which is, of course, squared with the frame). Then when the frame with its patient is adjusted so that the pins or "sights" coincide with the foreign object it will be seen that all three are coincident, and that the characteristic distortion caused by the angle of the rays has been eliminated (as shown in diagram A). Measurements, taken with the eye by means of the metallic grating, will thus enable the surgeon to discover unerringly the position of the object with reference to the surface of the limb which contains it.

"How far *in* from the surface of the body it may be, however, is, at this point, still unsolved. (See diagrams in Plate No. 73.)

"Marking the wrist between the vertical arms of the Fluorometer for convenience, and also marking the points indicated by the pins or sights, the limb still maintaining the same cross-section is given a quarter turn as shown in plate 72. The pins are again adjusted as before, establishing a new line through the bullet and the cross-section of the wrist as shown in diagram B. The position of the pins having been again marked, it will be found that the bullet is situated at the intersection of the two right lines as indicated in diagram C.

"The method of adjusting the pins or sight referred to is such

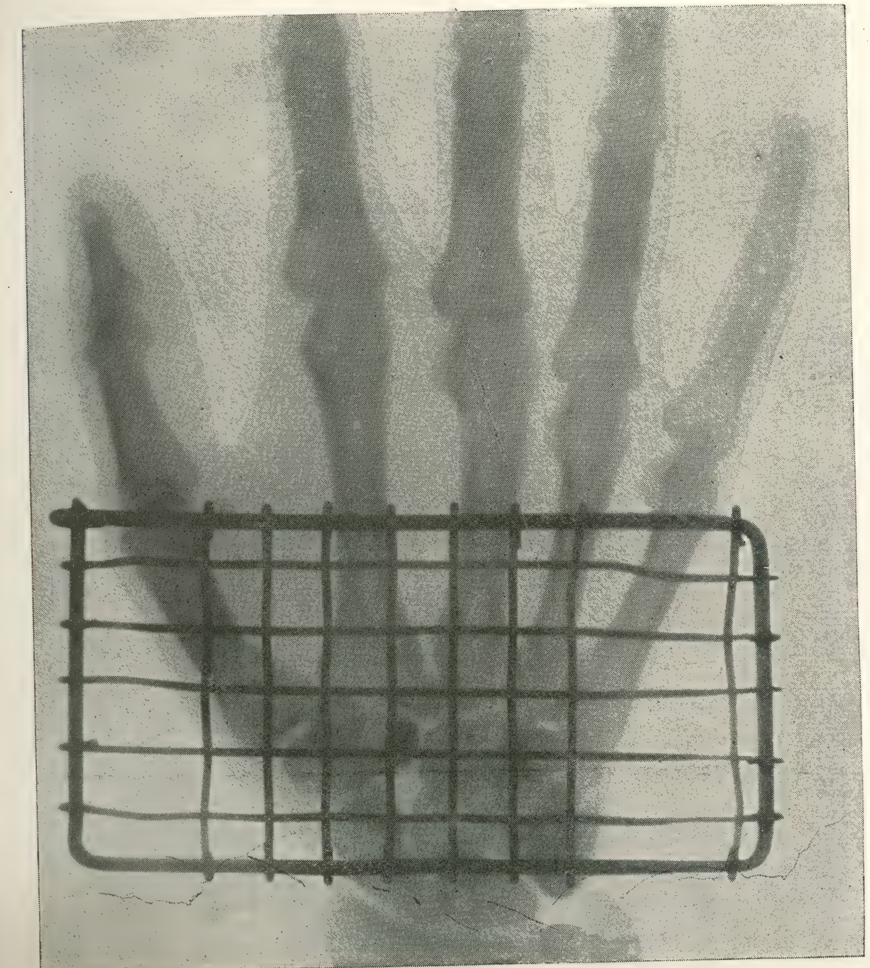


PLATE 70.—Primitive Localization. A method of localizing a bullet. This case is inserted to illustrate the phases of the growth of modern scientific localization. Says the surgeon: "The patient, a man aged twenty-one, came to the hospital three months ago with bullet in hand; hand much swollen and very painful. Took an ordinary radiograph, which plainly showed the bullet in the palm apparently resting on the bones of the carpus.

"With this picture before me I cut down to the bone, but even after prolonged search failed to find the bullet. I tried several experiments in localization by making lines on the hand with various paints of lead, mercury, and bismuth. All of these were photographed on a plate more or less distinctly, but did not show lines definite enough for the purpose. It then occurred to me to have a grid made of iron-wire as shown in photograph B. This was painted on one side with an aniline dye and fixed to the palm. The palm with the grid in situ was then placed on the sensitive plate, a layer of celluloid being interposed to keep the dye from the plate. The result was that the hand and the photograph were both marked by the grid. I then cut down a second time into the palm, and being quite sure that the bullet must be under the knife went further than before and found it wedged in firmly between the os magnum and trapezoid bones and nearer to the back than to the palm of the hand. I have since had a fine and flexible grid made which adapts itself to the part." (Rebman, Ltd.)

The defects of a method once deemed ingenious but now known to be far from true localization will be better understood by the reader after making for himself the tests suggested in our chapter on distortion. Many of the early complaints that bullets were not where the rays showed (?) them to be arose chiefly from the failure of the operator to place his tube so that the focus of the rays, the bullet, and the centre of the photographic plate would fall in a straight line perpendicular to the plane of the plate. This is easily done, but at first and even now, it is ignored by many. Compare with the Author's "One-Minute Localizer."

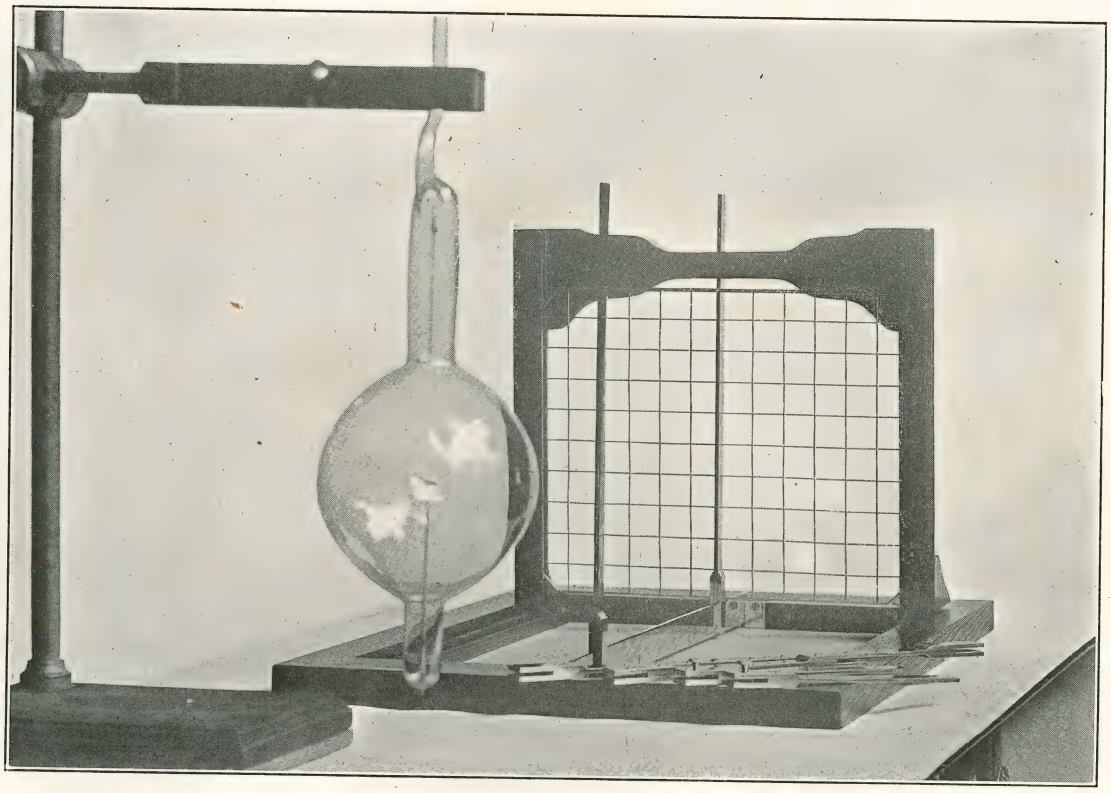


PLATE 71.—The New Fluorometer. Set up screen, bars, and tube as shown in this plate. Align the focus of the tube so that the bars cast one shadow on the fluoroscope. Insert the part to be examined as taught in the next Instruction Plate.

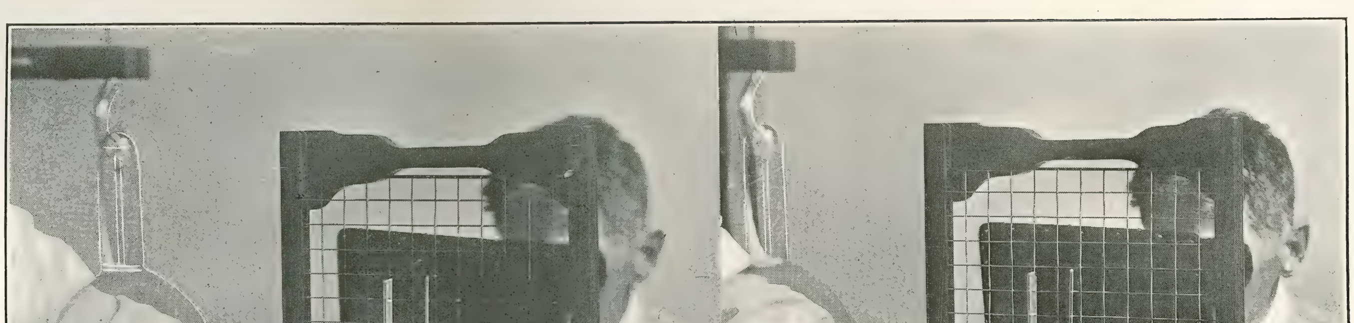


PLATE 72.—Locating a bullet near the wrist with the new Fluorometer. First mark the level of the shadow with the arm in position as shown at the left. Then make a quarter turn and mark the second cross-section. The next plate shows the result in diagram. The arm is here illustrated for simplicity, but the principle is the same in all parts of the body accessible to the fluoroscope. These plates are from advance photographs of the new model made especially for this work by the courtesy of the Rochester Fluorometer Company.

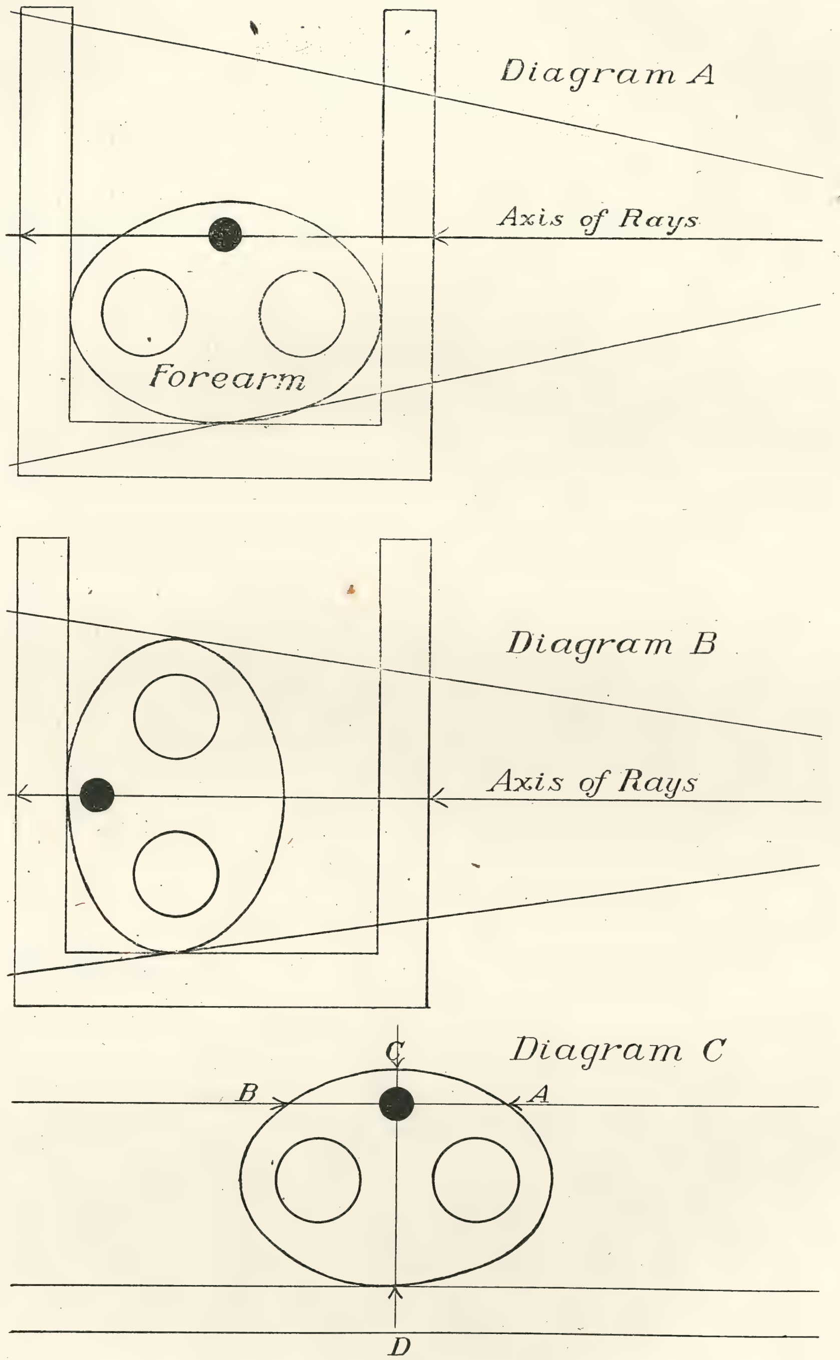


PLATE 73.—This diagram teaches the exact findings of the fluorometer when used as taught in the preceding plates and text.

that when the final observation is taken by means of the fluoroscope a light line intersecting the two sights and the centre of the bullet observed will be exactly parallel with the base of the instrument in each observation. Hence, by glancing at diagram C, it will be seen that the line AB secured by the first observation will intersect the line CD secured by the second observation at the centre of the bullet, thus unerringly indicating the position of the bullet on the cross-section of the wrist as shown by the markings on the surface.

"It will also be seen that, after the proper position has once been obtained, its undistorted record may be preserved by placing a sensitive plate in the upright plate and screen-holder. Medico-legal experts will thus be enabled to procure an undistorted radiographic view of any portion of the human anatomy, and can by means of the Dennis Fluorometer reproduce the position and its radiographic record at any time they may desire to do so.

"As shown above, the diagnosis produced by the Dennis Fluorometer will disclose to the surgeon unerringly the location of any foreign object, or the condition of dislocation or fracture. The instrument is the invention of John Dennis, Rochester, N. Y."

Localization by a Double-Focus Tube.—A paper entitled "A double-focus tube for the accurate localization of foreign bodies by the fluoroscope or photographic plate" was presented in November, 1899, by Leonard. In it he says:

"The technics required for triangulation methods seem to have been a barrier to their general employment, and to simplify the application of the same principles the author has had made a tube with two cathodes and two anodes, and hence two sources of rectilinear rays. This avoids the errors that creep in when the position of the tube has to be changed or separate plates used, and it has made rapid accurate localization with the fluoroscope easy. By it we can also avoid the delays necessitated by the development and fixation of a negative. The fluoroscopic method is as follows:

"Fix the screen in a perpendicular position. Place the tube horizontally so that the mid-point of the line connecting the two sources of rays is perpendicular to the plane of the screen, and at a known distance from the centre of the screen marked by an opaque cross. This is all the adjustment required, and can be readily made in a square. Place the limb containing the foreign body before the screen so that the two shadows of the bullet will fall equally distant on each side of the opaque spot and on the same line. The foreign body is on the line perpendicular to the plane of the screen at the opaque point. Mark the spot on the patient's skin with nitrate of silver.

"By placing an opaque rod on the other side of the limb, where its two shadows are equidistant from the opaque spot, the perpendicular is found and marked on that side. The foreign body, therefore, lies on this line at a distance from the opaque spot that is determined by measuring the distance between the two shadows of the foreign body with calipers and plotting the shadowy paths by the graphic process as when plates are employed, or by the cross-thread method."

Professor Barrell's Method of Localization without Plumb-Lines or Threads.—" In all methods of localizing the position of a foreign body it is essential that two distinct skiagrams should be taken, though it is convenient often to have the two pictures superimposed on the same plate. As is well known the position of the tube must be changed between the taking of the first and second picture, and the distance which the focus has moved must be known. Further, it is essential to know the points on the plate where it is met by lines drawn perpendicular to it from the focus. In all existing methods of localizing the position of these points is ascertained by use of the plumb-line, and in order to secure any accuracy in the results *the plate must be levelled* before the pictures are taken. The use of plumb-lines is at all times fussy and annoying, and is especially so when the point from which the plumb-line *ought* to be suspended is an invisible 'focus' situated somewhere in the middle of the glass bulb.

" Having mastered the difficulty of the plumb-line there also remains in most methods the further trouble of stretching two fine threads, and measuring the position of the point where they cross each other.

" My method requires no *plumb-line*, no *threads*, and no *levelling*. My apparatus consists of two metal cylinders whose ends have been carefully turned perpendicular to their axes. A convenient size is four inches by one inch in diameter. Place these cylinders upright on the plate during an exposure and close to the limb which contains the foreign body. The shadows thrown by the cylinders indicate the position of the focus of the tubes. To secure a good long shadow, place the cylinders near the end of the plate farthest from the tube. After the first exposure shift the tube six or ten inches. Then shift the cylinders toward the opposite end of the plate and make the second exposure." (See Plates No. 74 and 75.)

Sweet's method of localizing a foreign body in the eye has been taught as follows: (See Plate No. 76.)

" For this purpose an indicating apparatus is used carrying two steel rods each with a rounded end. The indicators may be supported by a head band, and the plate held to the side of the head by an ordinary bandage. The balls of the indicator are at a known distance apart, one pointing to the centre of the cornea, and at a known distance from the eye-ball, while the other is parallel to the first, toward the external canthus. The visual line is parallel to the indicators and to the plate. The ball should also be perpendicular to the plate. In making the negatives the tube is in front, about thirteen inches from the plate, and at an angle of from fifteen to forty degrees, with a vertical plane passing through the apex of each cornea. The plate

is at the opposite side of the head, and the rays pass through the eye-ball and the external orbital-wall before reaching the film. Two exposures are made, one with the tube in a horizontal plane, or nearly so with the two indicators, and the second at any distance below. The angle of the tube below the horizontal is unimportant so long as two exposures give different relations of the indicators on the negatives.

" In determining the position of the foreign body in the eye, two circles, twenty-four millimetres in diameter, equivalent to the size of the globe are drawn upon paper. One circle represents a horizontal section of the eye-ball and the other a vertical section. Upon the vertical section a spot is marked at the centre of the circle indicating the position of the centre indicator of the apparatus. The distance between the two indicators is measured toward the temporal side, and a spot made to show the position of the external indicator.

" On the circle representing a horizontal section of the eye-ball a spot is made anterior to the centre of the cornea, and at the same distance that the centre indicator was from the eye when the radiograph was made. Another spot to the temporal side, measured by the distance between the two balls of the apparatus, marks the situation of the external indicator. Taking the first negative with a tube nearly horizontal to the two indicators, measure the distance of the foreign body below to the two balls of the apparatus. These measurements are indicated on the circle representing the vertical section of the eye, and a line is drawn through the point. Somewhere along this line is situated the foreign body.

" From the second negative, made with the tube below the plane of the two indicators, the measurement is taken of the distance. The shadow of the foreign body is below the centre indicator, and this point is indicated in the first circle. The distance the foreign body is above the external indicator is measured, and the point indicated on the circle. Where a line drawn through these points crosses the line of measurements made from the first plate is the situation of the foreign body as respects its horizontal and vertical position in the eye-ball.

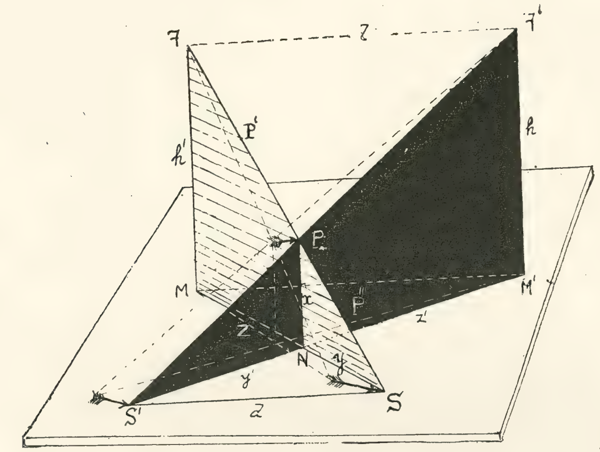
" To determine the distance of the foreign body behind the apex of the cornea, the negative made with the tube nearly horizontal is taken and a measurement made of the distance the shadow of the centre wall is posterior to that of the external ball. The distance is entered directly above the external wall on the diagram representing the horizontal section of the eye. From this point a line is drawn through the ball of the centre indicator, which indicates the direction of the rays from the tube when the exposure was made. Taking the negative again, we measure the distance that the shadow of the foreign body is from that of the external indicator. The distance is marked perpendicularly to the spot representing the ball of the external indicator on the diagram, and a line is drawn parallel to the direction of the rays from the tube. Where this line cuts a line perpendicular to the position of the foreign body shown on the vertical section of the eye-ball is the distance of the foreign body behind the anterior portion of the cornea.

"In working out the position of the foreign body certain factors are essential; a tube should be used of high efficiency in order that the rays may readily penetrate the bones of the head with a short exposure. The patient should be in a position to insure absolute steadiness of head and body. The visual axis should be parallel with the plane of the plate at the side of the head. The situation of the indicating objects with respect to the centre of the cornea must be known factors. The angle of the tube with the indicating objects must be accurately measured."

Davidson's Localizing Apparatus.—Modifications of this apparatus are portable and less expensive than the original, which perhaps reaches the high-water mark of scientific accuracy and universality of application in the hands of an expert. A complete equipment of the localizer, the tube-carrier, and the head-rest for eye work was brought by the author from London in 1898. The description of the originator is as follows: (See Plate No. 77.)

"The extended use of the X-rays has led to an increasing need for some simple method of localization which can be at once readily carried out, and at the same time be reliable. The method I have devised is of this character. It was, of course, obvious from the first that taking the skiagraph from two or more points of view was a necessary starting point to any method of localization. But the question of *how the resulting photographs were to be dealt with to give the desired information* remained a difficulty, except to the comparatively few who were sufficiently familiar with geometrical drawings and mathematics. My method is as follows: I take two skiagraphs from two different points of view. In order to carry out the adjustment and movement of the Crookes tube I use *a horizontal bar with a scale upon the front of it graduated in millimetres* with zero at the *middle point* of the bar. This bar slides up and down upon two brass rods which rest upon the floor on a base like a standard lamp. The bar can be readily detached at one end and opened like a gate to facilitate the placing of the patient. A small holder carrying the Crookes tube slides horizontally along the bar, and there are two stop-pieces with set-screws which permit the tube to be quickly moved and accurately fixed from any position on one side of zero to the same position on the other side.

"To adjust the Crookes tube to a particular height is a small bar applied vertically carrying the tube up and down with it and acting as a *fine* adjustment. It is fixed with a set-screw. A small spirit-level is inserted on the top of the cross-bar. This part of the apparatus is simply a convenient method for shifting the tube in taking the two skiagraphs, and somewhat similar arrangements have been used before.



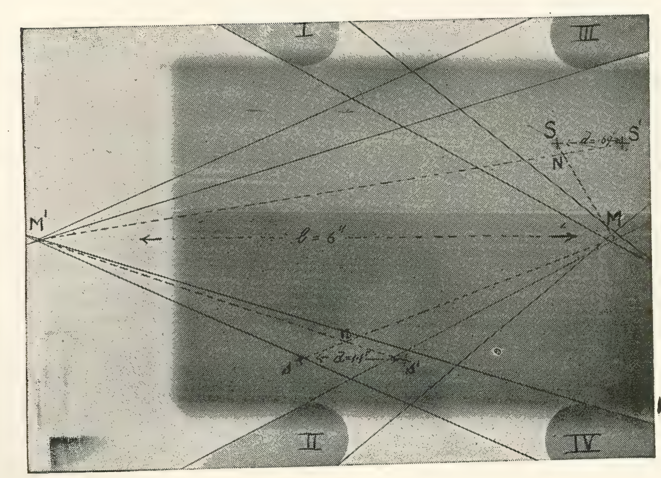


PLATE 74 (1) and (2).—Illustrating "A New Method of Localization without Plumb-lines or Threads," by Professor Barrel. See text for description.

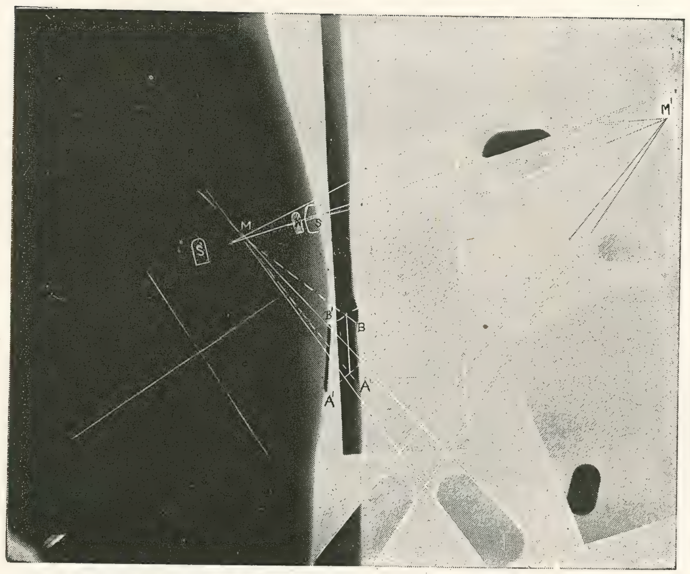


PLATE 75.—Bullet Located by Mr. Barrel's Method. Three distinct indices were fixed to the patient. The first was a small cross of tin-foil, which is readily visible in the negative, but can only be detected in the print by the white cross rising from the lines by which it was marked out. No use was made of this index. The third index, the only one used, was a narrow strip of lead fixed between two prominent marks left by the stitches near the outer part of the gluteal fold. The patient lay on his back so as to about half cover a 10 x 12 plate, leaving plenty of space on which to stand the localizing cylinders. Two exposures on the same plate were made, each three minutes, with electrolytic interrupter. The position of the bullet having been ascertained the patient was made to again lay on his back on a drawing-board. A mark was made on the skin at the indicated height, and the position of the bullet located. (Rebman, Ltd.)

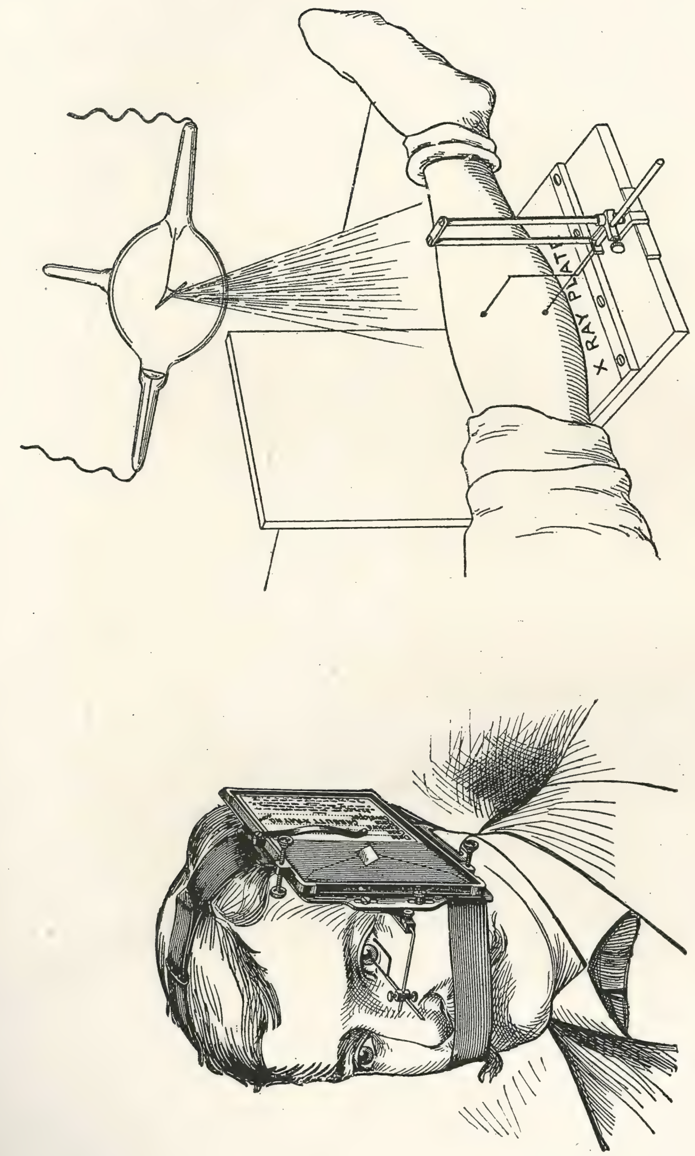


PLATE 76.—Method of arranging this form of localizer upon the side of the patient's head for foreign body in the eye, and also showing one method of similarly localizing a bullet in the leg. The principle is made clear by the illustration.

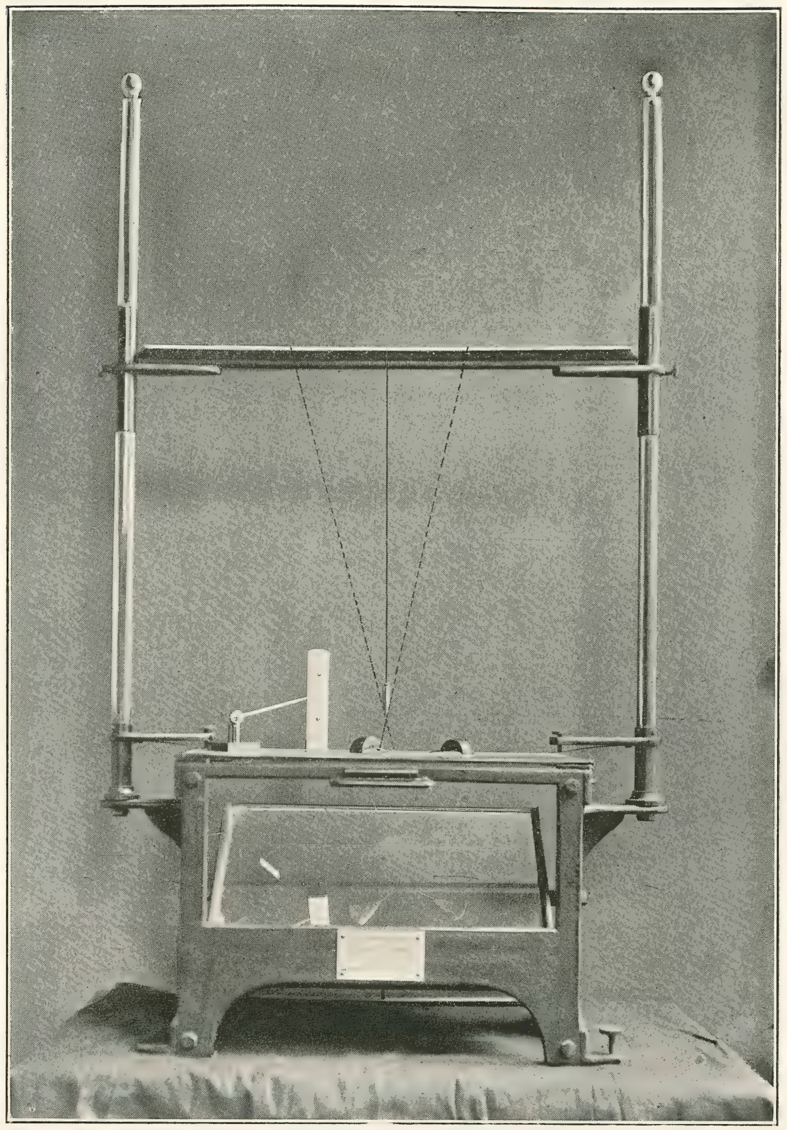


PLATE 77.—Author's duplicate of the original Mackensie-Davidson Cross-Thread Localizer. The mirror below reflects up the light through the negative on the levelled glass plate. The pointer and vertical scale are seen on the left. The mouse-shaped weights end in needles holding the threads. The cross-bar with its millimetre scale can be set at any distance from the base and must be the distance from anode to film when the negative was made. The plumb line suspends a lead pointer at a height above the plate. The dotted lines, equidistant from the centre, start from the two foci of X-rays in the exposure. They cross at the end of the plummet and end at the two shadows on the negative. Simply measure the distance from the plate to the crossing of the threads, and we have the depth of the body from the surface of the tissues that was on the film of the radiograph. First make a proper double radiograph and the rest is simple. See full directions in text.

"*Method of taking the skiagraph.*—Place the tube in the sliding holder. Place the sliding holder with one of its edges on *zero* in the centre of the horizontal bar. Adjust the two check-clips three centimetres to the right and left of zero. On the operating-table below the tube place the plate-holder and then drop a small plumb-line *perpendicularly from the focus-point of the anode.* Then move the plate-holder so that the *centre* where two wires cross and divide the plate into four quadrants *is exactly under the plummet-point.* Also sight it over the edge of the horizontal bar and lay the plate so that the *hori-*

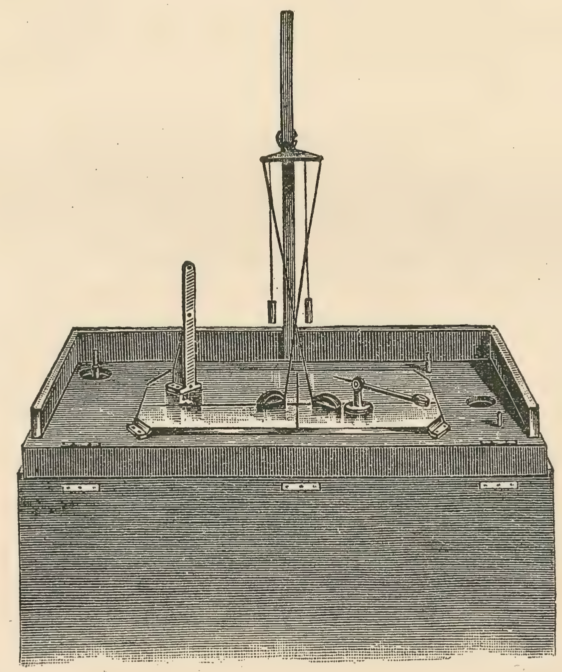


FIG. 15.—A modification of the cross-thread device for readily finding the depth of any foreign body in the tissues after making the preliminary double radiograph. It is designed for portability. See Plate No. 76 for picture of the finer original apparatus.

zontal wire exactly agrees with the horizontal bar. Next adjust the tube at the desired height. Make an exact measurement of the distance between the surface of the film and the exact surface of the anode, as any variation in recording this distance will affect the results. Now move the tube-holder till it meets a check-clip on one side of the centre. Brush the cross-wires over the plate-holder with marking ink and bring in and insert the plate under the cross-wires. Now place the part of the patient to be photographed in position on the plate and lay a small metallic object on one of the corners of the plate to identify the quadrant. Switch in the current and make the exposure as usual.

"At the end of the first exposure cut off the current and slip the tube-holder over to the opposite check-clip, a lateral displacement of six centimetres from the first position. Then make a second similar exposure *on the same plate* and without the patient moving. At the end of this exposure develop the negative in the usual way, and it will contain two shadows of each body opaque to the X-rays. The patient will be marked by the cross-wires on the lower surface of the skin, and with ink I also mark the quadrant on which the metallic marker was placed. It is also an advantage after the part is in position for exposure to again drop the plumb-line from the tube and *mark the centre on the upper surface of the skin.* By dropping the plummet from zero and from each of the check-clips and marking the line on the skin crossed by another line at right angles from the centre it will mark the *upper* surface to correspond to the cross-wire marking *below.*

"By means of the above data the position of the foreign body can be worked out by a mathematical formula, but as everybody does not recall his mathematics easily I have devised a method of dealing with the result which is accurate and within the reach of every one who can use a foot-rule and a pair of compasses.

"The *localizer* resembles a photographer's *retouching desk.* Upon an iron stand a piece of plate-glass is placed horizontally, with a spirit-level. Below is a mirror which can be adjusted to reflect up the light from a window or a lamp. Above, a horizontal bar slides up and down on two vertical brass rods. On the cross-bar is a millimetre scale with a small notch at each millimetre mark, and *zero* is in the centre. On the glass plate are cut two lines at right angles to each other, *marking the plate as the cross-wires mark the negative.*

"This glass plate (which is movable) is so placed that the point where the lines cross is vertically beneath the *zero on the scale above,* and the line on the glass running right and left as the operator faces the scale is placed *parallel to the edge of the scale.* The scale is now raised or lowered so as to make zero on it *precisely the same height above the negative as the distance between the anode and the film when the negative was exposed.* With a slight washing after fixing the negative can be at once placed upon the horizontal plate of the localizer and easily adjusted so that the lines produced by the cross wires *register with the lines cut in the glass plate, and the marked quadrant is in the same relative position as it occupied in the exposure.* As a routine practice I always mark the upper *right* quadrant as I stand facing the scale on the bar. To protect the wet gelatine surface of the negative, I place a sheet of very thin mica or celluloid over it. If it be a film, I place it face downward and squeegee it. It thus remains fixed and the celluloid is so thin that the thickness may be ignored in the subsequent measurements, but it is important to remember that if the negative is placed with the *gelatine surface downward* the relations of the parts are *reversed.*"

"The *negative* is thus placed under exactly same conditions as

existed when it was taken, and all that is now required is to trace the path of the X-rays which produced the negative. I do this in a very simple way. With the apparatus are two white silk threads with a small weight on one end and the other threaded into a fine needle which is fixed into a piece of lead shaped like a mouse.

"Place one of these threads in the notch as many centimetres to the right side of zero as the tube was *displaced* to the right during the exposure. Place the other thread in the corresponding notch on the left of the centre. Run these two threads down to the film and let the eye of each needle rest on the point of the *shadow* of the foreign body made by the corresponding focus of the tube. *These two threads then reproduce the path of the X-rays.*

"First measure the vertical distance from the negative to where the threads cross each other by means of an ordinary pair of dividers. This is the depth of the point of the needle *beneath the skin of the patient* which rested on the photographic plate, assuming that we are now locating a needle in the arm. A surface gauge is furnished for easily making this measurement. Next measure the vertical distances from the shadows of the cross-wires to the points where the threads cross. An upright square belonging to the apparatus is placed with its edge coincident with the shadow of one of the wires, and the perpendicular distance from it to the point where the threads intersect is measured with compasses. We now note down the result as shown in figure.

"We then ascertain the position of the eye of the needle in a similar manner, and the distance between the two points when connected by a line gives *the direction and actual length* of the needle in the tissues. From the measurements jotted down we can mark on the patient's skin a line in the same plane as the needle and give the surgeon the exact depth at which each of the extremities can be reached by a vertical cut. A final result of the process is that you can draw an outline of the foreign body of the patient's skin, and give the depth below the skin of any of its parts. While lengthy in description, it is rapid and reliable in practice, and can be done very quickly after a few trials. Triangulation automatically by means of these threads and this scale device is capable of wide application. It will also prove useful in the measurement of bones, displacements, and especially in pelvic measurements. Provided two fairly well-defined double skiagraphs, preferably on the same plate, can be obtained, the measurements cannot fail to be accurate."

The most remarkable results in exact localization with this apparatus have been obtained with foreign bodies in the eye. Nearly a year ago Davidson had a record of more than 250 eye cases, and so accurate are his results that a particle of steel of the smallest size in any part of the eye-ball can be cut down upon and extracted with the precision and certainty of sight. In respect to eye work, at least, Davidson's technique outclasses all rivalry in this field, and, having personally witnessed his work, the author can vouch for its simplicity and success.

Most of the difficulty of localizing with this almost automatic device will result from first making the negative *without regard to the situation* of the bullet or other foreign body. If the exposure is made with the bullet *aligned* in the axis of the rays it will be right over its shadow on the plate, and the *depth* will be *the distance from the film to the crossing of the threads.* In regular use the cross-bars of the exposing-table and the localizer can be kept in permanent adjustment to correspond, and then the mere placing of the leaded ends of the threads on the shadows on the plate will automatically show the depth at once. No figuring is required, and the distance between the cross-point and the film is noted by a pair of dividers. Fine work within the eye will require special training, but apparently all general parts of the body present a minimum of difficulties to this classical method. Make the first steps of the process correctly, and the rest will easily follow.

The Remy Localizer.—The localizing apparatus of Dr. Remy can be used with either the fluoroscope or negative, and weighs but a few pounds. It is constructed entirely of metal, and when taken apart is carried easily in a box about 7 × 18 inches in size. An open screen is required, as the box of the regular fluoroscope interferes. It takes the principle of two crossing rays, and, instead of threads, it represents the two paths of the shadow by two metallic rods, which show the depth of the bullet by converging and meeting. The depth the rods are moved down the frame before their points meet equals the depth of the bullet in the tissues. The use of this device is illustrated in Instruction Plates No. 78 to 83 inclusive. The author's description is as follows: *

"Suppose a rectangular plane. Assume that the upper edge of the rectangle intersects two foci producing X-rays. The rays from one focus cross those proceeding from the other; but it is always possible to determine to which tube any one of the rays belongs, whatever may be the point in the plane at which we place ourself.

"Let us now neglect all that part of the plane touching the tubes; the direction of the rays will then be represented only by lines of a few centimetres in length, but by prolonging these lines we will reach the centre of each of the foci. Let us now interpose between the tubes and the remaining part of the plane a fluoroscent screen, and interpose an opaque body to the X-rays, the shadow of which is thrown on the luminous screen. If the foreign body is in this plane, its shadow will

* Archives of the Roentgen Ray.

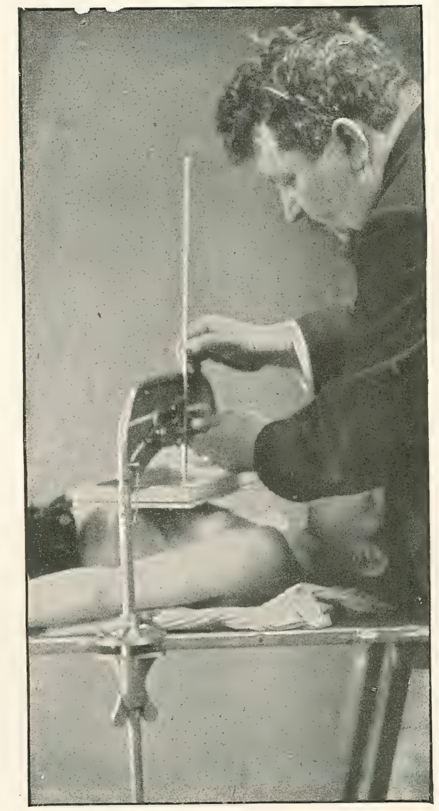


PLATE 78.—The Remy Localizer. First position. With the first tube below throwing the shadow of the object on the screen seen on the chest of this patient push down the first rod in the axis of the rays till its point marks the centre of the shadow. This rod then resembles one of the threads in the more familiar "cross-thread" localizer.

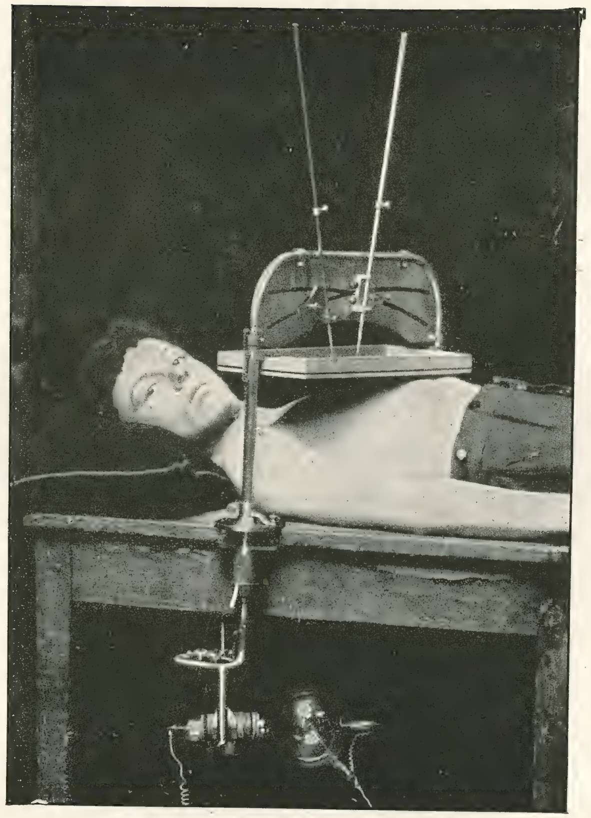


PLATE 79.—Remy Localizer. Second position. Move the tube horizontally to the focus for the second shadow on the screen and push down the second rod to meet the centre of this shadow. The two rods then are the equivalent of the axis of the rays from the two foci.

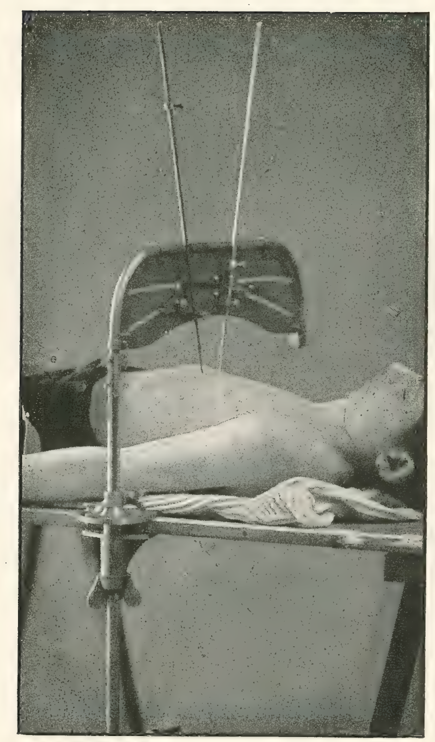


PLATE 80.—Remy Localizer. Third step. Having the two rods converging on the two shadows, remove the screen and push down the rods till they touch the skin. If they were now carried into the tissues till their converging points met the bullet would be at that situation, exactly as it is at the point of intersection of the cross-threads in the Davidson apparatus. The principle of both is the same, though Remy uses rods beyond the field of the rays, and Davidson uses threads within the field of the rays.

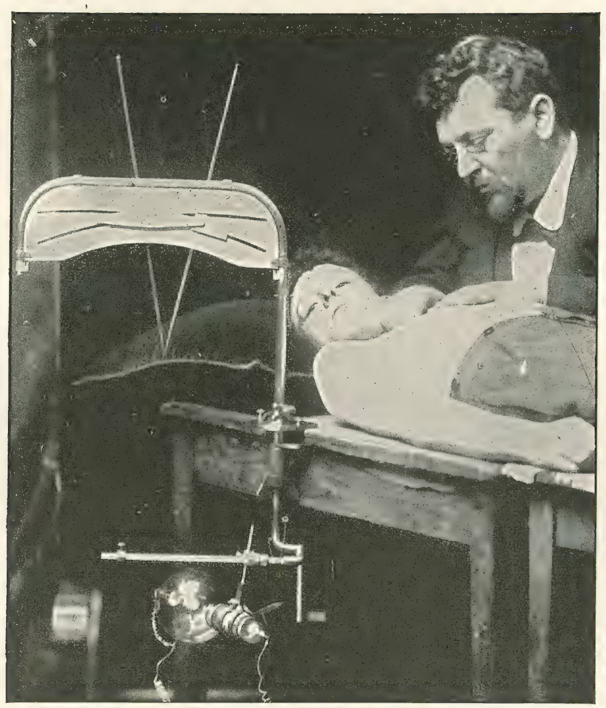


PLATE 81.—Remy Localizer. Fourth step. Now mark the two points on the skin touched by the tips of the rods. Swing the frame aside out of the way as shown in this plate. When the rods are free from the patient note the distance of the points below the frame. Then push down the rods till the points meet, and note the exact distance this is below the last position. The first measurement is the surface of the body and the last measurement is the depth of the bullet below the surface of the body in the direction shown by the two rods. The mechanical accuracy of the method is complete. During the operation the frame can be swung again into place as often as needed to verify the direction and approach to the object sought.

necessarily be found on the prolongation of one of the lines traced on it. Each of the tubes will give us a different shadow corresponding to a different line; thus, two different X-rays will exist, which we can represent in the form of rods prolonging the lines, and so know the point of intersection required—that is to say, the seat of the foreign body.

" *The seat of any foreign body visible by means of the X-rays will be shown to us when in this plane. If the foreign body is not in the vertical plane on which the direction of the X-rays is known to us, we must bring it into it, either by altering the position of the patient or that of the plane.*

" *Practical Application.*—A frame, with two opposite bars, one of which supports the two Crookes tubes, and the other a small tablet, represents the working plane of which we have just spoken.

" A system of sights allows the foci of the tubes to be always placed at the same points. On the tablet opposite, the direction of the X-rays proceeding from these foci is, with the help of the following device, represented by two steel rods:

" Two grooves describing arcs have been scooped in it, the respective centres of which correspond to the foci of the Crookes tubes. In these grooves run rings bearing rods, the imaginary prolongation of which will intersect the foci of the tubes at whatever point of the tablet they may stop.

" The frame which represents the plane must be of a considerable size—at least thirty inches wide—so that a man's body can be introduced into it.

" *Mounting of the Apparatus.*—The vertical part consists of a hollow rod, entering smoothly into a holder, and able to move freely in it. It can rise, descend, and turn. A ring placed above the holder limits the vertical movement, but allows a rotatory movement. A sort of arm which prolongs the ring indicates on a sliding rule the changes of position, and allows them to be marked.

" The holder is fixed on the edge of a table. The lower horizontal part is fixed by means of a tenon on the hollow rod. It carries the clamps which hold the Crookes tubes, two stops, and a sight. The upper horizontal part or tablet is fixed to the hollow rod by an intermediate portion, the bottom of which fits into the vertical rod, and the top holds the tablet. On the latter are the rings and the slide working in the grooves. The rings serve as sights.

" The apparatus will be ready for use when the Crookes tube has its focus at the point marked by the sights. To accomplish this, first bring round the anode so that its edge is on the line of the sight of the inferior piece; then draw out the rod from the tablet, and look through the holes of the rings it has just left. When the focus of the anode is in their axis fix the stop against which the clamps rest.

" Adjust the second focus in the same manner. A single Crookes tube can suffice for the two foci by sliding it along the lower rod. The screen is hooked on under the tablet.

"You have now only to fix the holder on to the edge of the table where the wounded person is laid.

"This table must have a top of thin material so that the X-rays may pass without any diminution of their intensity.

"*Instruction for Using the Apparatus.*—Let us suppose we have a patient with a projectile in the chest. He is on the wooden table. Place the thorax between the tube and the screen. Put the screen as near as possible. (See Plate No. 78.)

"Sight a tube; the shadow of the foreign body will be projected somewhere on the screen; move the tablet round so that the shadow may lie in its plane. Take hold of the rod which represents the X-rays proceeding from the tube in activity; bring its point to the centre of the shadow thrown on the screen (Fig. 78). A second shadow is next obtained with the same tube placed at the second focus. Bring the second rod into contact with it (Fig. 79). Mark on the skin exactly the plane on which you are. That done, take away the screen. By lowering the two rods their points will arrive at the skin of the subject (Fig. 80). If we now pierced the tissues we should reach the projectile, but we must first ascertain its depth. To do this two ways are open to us:

"1. Without moving the apparatus take a sheet of paper folded in two; place it against the two rods, taking care that it touches the skin at the place where it is folded. With a pencil draw two lines on the paper using the rods as a ruler; this done unfold the paper and prolong the lines which stop at the fold. You may see immediately the point of intersection of the lines: the projectile is at this point.

"2. By removing the apparatus away from the body with a rotatory movement on its lateral axis we can slip down the rods till the points meet (Fig. 81). Then fix on each rod a small indicator at the level of the rings. Then bring back the apparatus into its original position, and again apply the points of the rods on the skin. You will see how much the indicators have gone up. This equals the depth of the bullet.

"*The ideal we aim at is to be able to extract the projectile on the table, and with the apparatus which has already served to determine its position.* This being determined, we clear the field of operation. Then, if necessary, by a simple movement, we can again bring the apparatus into place and its guiding needles will direct us in the depth of our incisions, provided we have marked the plane of the foreign body. This can be done with mathematical precision. A horizontal stop placed on the holder of the apparatus allows us to ascertain exactly the angle of rotation, and consequently to bring back the frame to its first position. Once, twice, or ten times, we can begin again without ever making a mistake.

"*Objections and Questions.*—1. An objection has been made to me as to the necessity of having a dark-room in order to use the apparatus with the open screen. Reply.—A simple black veil, covering the screen and the head of the operator, has enabled me to localize foreign bodies in full daylight.

"2. The rapidity of the operation by which the position of the projectile is determined is such that I proposed to profit by the period of muscular resolution induced by anæsthetics to perform it and then operate immediately. A surgeon objected that the anæsthetic immobility would not be sufficient—that the efforts to vomit and other causes might produce movements. Some means of holding the patient would be necessary, he said. To this I reply that good anæsthetics have often given me a duration of muscular resolution, not only sufficient for the localizing, but for the extraction of the projectile; besides, means of securing immobility, either by plaster or otherwise, are not wanting.

"3. One difficulty in the application of the apparatus presents itself: it may happen that in the course of an operation the surgeon may be prevented from following the path of the X-rays. For instance, suppose that on the line of penetration he meets with the eye-ball or any other organ which it is important to preserve. He must abandon the straight line and take an indirect one. In such a case, we propose the use of the following method: The foreign body is to be found, as we know, at the point of intersection of two materialized X-rays. Suppose that one of our rods is of a flexible metal; it could then be bent from the groove to the point without ceasing to touch the point of intersection. This curved line will continue to serve as a guide to the operator. A series of articulated rods would answer the same purpose; the last would have a groove, and, according to circumstances, could be fixed either on the materialized X-ray or on the metallic tablet.

"*Radiography.*—When we have had recourse to radiography, we have been obliged to render the apparatus immobile in order that the first shadow projected might be clear, and to take care to move nothing so that the second shadow might be in the plane of the first.

"The plane passing through the two foci, the foreign body, and its projected shadows, is therefore, in this case, a fixed plane. As it does not necessarily pass by the focus of the tablet this latter must be displaced and brought into the plane to allow the localizing to be effected. We can be sure that if the tablet turn round the arc of the two foci producing the X-rays, it will not fail to pass into the above-mentioned plane. To this end we have constructed a separate connecting-piece on which the tablet fixed to a slide can slide and describe the necessary movement.

"*Mounting.*—The intermediate piece of the screen apparatus is removed. The connecting-piece is placed in the hollow vertical rod and fixed perpendicularly to the lower branch. The photographic frame is attached to it.

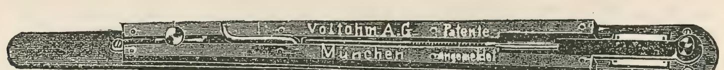
"On the connecting-piece is a slide to receive the tablet, which is exactly at the same distance and in the same position as for fluoroscope. The visual line passing by the rings which serve as sights corresponds to the centre of the anode. In practice one may successively use both processes by changing the intermediary piece without having to regulate the position of the tube.

"*Manner of Using the Instrument.*—It will vary with the parts of the trunk or head under observation, and depends on whether they are thick or not. For the trunk fix the vice on the edge of the table at the right place, already determined by a previous radiograph. Fix the rod which bears the foci by tightening a screw of the vice. Fasten the photographic frame to the curved piece. Draw out the first photographic plate. Develop it. Replace the first plate in the frame. A marking index allows you to replace it exactly as for the first exposure. Slide the tablet along the curved piece so that the rod representing the X-rays touches the first shadow. Do the same for the second proof with the second focus, and then finish as in the use of the screen.

"For radiography of the head the direction of the apparatus must be changed in order that the X-rays may meet the skull on its lateral face. To accomplish it, the vice is unscrewed, the rod laid on the table, and the connecting-piece which surmounts it fixed on this table by means of two screws. The rod into which slide the tubes, the frame, and the tablet becomes vertical. The head is placed as near as possible to the frame; it is raised a little above the level of the table by a block, and held by a band of aluminium. This band, transparent for the X-rays, serves at the same time to insure immobility and to give marks for the operation. If the needle which has served to determine the seat of the projectile cannot serve as a guide, fix on to the aluminium band another metallic rod, either jointed or flexible, as we have already indicated in the directions for radioscopy.

"*Duration of the Experiments.*—The duration of time required for radioscopic localization is *two minutes*. The duration of the radiographic process varies from nineteen to thirty minutes. We have succeeded in shortening it by taking two radiographs on the same plate, but cannot always rely on a good result from this double exposure. The apparatus can be sterilized."

The Punktograph.—A German device for localizing foreign bodies with the fluoroscope is called the Punktograph. The instrument consists of a brass ring mounted on an ebonite handle, with a dermal pencil, also mounted to the base, so that when released from a check-



THE PUNKTOGRAPH.

spring, it will protrude through the centre of the brass ring and mark the skin against which the ring is pressed. Two of the instruments are required for a cross-section localization. Either an assistant or

a stationary fluoroscope will be required so as to leave both hands of the operator free. Assuming that a bullet is buried in the forearm it is engaged so that when the rings of the two Punktographs on opposite sides of the part are in line with the axis of the tube, the bullet will fall in the same line. The pencils are then released and dots marked on the skin. A similar observation is repeated through an opposite cross-section, and the bullet will be at the intersection of lines drawn through each.

The principle is the same as all methods of multiple observation, whether with the radiograph or with the fluoroscope. It will be noted that if the two rings are of the same size, the one nearest the tube will be larger than the one near the fluoroscope, and some care will be required to obtain a fairly approximate localization by this method. See also the ring-markers in the set of balls, points, rods, and rings supplied as accessories to the author's One-Minute Localizer.

Shenton's Method.—The following method of localizing is described by Shenton.

"For such cases as needles, or bullets in the hand, arm, or leg—that is, in parts easily manipulated—no special apparatus is required and no photographic process involved. Proceed as follows: Hold the part—for example, a hand containing a needle—before the fluorescent screen. Start with the screen and the anode in the tube as nearly parallel as possible. When needle and bones are distinctly seen sway the screen and hand from side to side and note the change in relation of bones and needles. It is evident that the image of whichever is farthest from you and from the surface of the screen will move the faster. If the needle moves across the bones its position is deeper than the bone; if bones move across needle the latter's position must be between the surface of the screen and the bone.

"Should the needle appear to remain stationary, place a pointer against this image on the screen and ascertain whether it moved a little or not at all. Verify these results by reversing the hand and repeating the manœuvres. A little practice enables one to give as near an estimate of the needle's real depth as any surgeon could require, and such suggestions as 'just beneath the skin of the palm,' 'midway between bones and skin,' 'lower end between bones,' 'upper end one-eighth of an inch between the skin of the back of the hand,' are in my experience sufficient for any operator. I doubt if a calculation in millimetres would be of more use. The body is an awkward thing to apply the millimetres scale to, and a little pressure on the skin, or a little swelling beneath it, will overthrow such minute calculations.

"The needle's depth being ascertained, it only remains to find its position in the horizontal planes, a task which presents few difficulties. When found this position should be marked on the skin. The advantages of this method are its rapidity of performance, the process taking but a few seconds, and the economy of material, both photographic and electrical.

"For localization in other parts of the body, and for photographically recording results, I have constructed an instrument which in principle is the same as the method just described, save that the tube is swayed while the part viewed is held in position by bands and tension springs. The tube is moved by the observer from his side of the screen, the distance it travels being regulated by sliding stops. A fine vertical wire is stretched in the centre of, and in contact with, the screen. The image of the foreign body is made to correspond with this line when the tube is in the mid position. Upon moving the tube from the extreme right to the extreme left, the image of the foreign body on the screen is seen to pass from left to right. Its relative rate of travelling compared with the same portion of bone is noted as before.

"For accurate measurement the true position assumed by the foreign body is marked by pencil on a celluloid film in contact with the screen. This measurement being secured, the distance the tube travels and the distance from the wire and the mid-point of the line adjoining the two extreme positions of the tube must be ascertained. A simple rule-of-three sum will now give the distance of the object sought from the screen."

The reader who has now carefully perused this chapter will have acquired instruction in every principle involved in the exact localization of any foreign body by the aid of the X-rays. Technics can be multiplied, but the basic principles are few. Gradually what seemed at first to be a most complex and vague process has been shown to be a mere mechanical detail that any one can work out. What early writers directed us to do with pencil and computations later ingenuity offers us means to ascertain without "formula" and without complicated apparatus. Some of the methods here described are very simple and practical, though they take up much space in the description, but it is always easier to demonstrate technique than to write it out.

An Emergency Case.—But stepping aside from the consideration of exact methods with a full equipment at hand let us take an emergency case and see what can be improvised to locate a bullet before a primary operation. Suppose a man is shot point-blank in the abdomen and must be treated where few surgical and no X-ray facilities are at command. An operation is decided on. The wound will be opened, cleaned, and sutured. The bullet is "probably" lodged in the muscles of the back, where it may become encysted and do no harm, but it is desirable to know where it is and ascertain its relations to the operation. Granted that there is no X-ray apparatus at the bedside, there

are several in the city, and a truck can move one as fast as a horse can draw a cart. While preparing the patient, telephone one that can be moved most quickly, and in fifteen minutes or a half hour it can be at the operating-table.

But none of the surgeons have any localizing instruments and do not know how to use any. They have not studied localizing technics. They are in haste to get at the wound and care little for the bullet. Nevertheless, it will delay only a moment to find it, and then during the operation it can be taken out. Let the surgeon go ahead with his preparations. Let the anæsthetizer begin. Tell an assistant to connect up a tube. As soon as the muscles relax run the tube over the abdomen five inches from the skin and light it up. Let an assistant drop under the table with the fluoroscope and find the shadow of the bullet, which is undoubtedly near the back. When found have another nurse move the tube so that it is vertical over the bullet, being directed to the proper position by the watcher with the fluoroscope under the table. Then let the nurse lay on the abdomen a pair of artery forceps and move them till the fluoroscope shows that the bullet-shadow is rimmed by one of the handles. Then have the nurse slip any long metal instrument with a small tip under the back and shift it till the fluoroscope finds the tip in the same line as the shadow of the bullet. The job is nearly done now. It has taken only while the surgeon is washing his hands, and has delayed nothing. Let the assistant at the fluoroscope still, for a second more, sight the line of the shadows as above. Let the nurse shift the tube a foot or so horizontally. How much has the shadow of the bullet left the line of the front and back markers? If very little, the bullet is very near the back. If very much, it is nearer the front wall than was supposed. The watcher with the fluoroscope can judge the approximate depth by the comparative amount of movement out of the line. Then all is ready. Remove the tube; note that the bullet is in the line between the front and back markers at an estimated depth from the back; let a nurse register the location; and proceed with the surgical treatment of the case. As sterilized instruments were used the operating field has not been interfered with, and the time required has been part of the general preparations. The absence of complete apparatus has not presented an insurmountable obstacle to localization. Having found the site of the bullet the question of its removal can be discussed in the light of exact knowledge instead of ignorance.

In these directions it has been assumed that an operation was planned. The records of war (and some of them are stated in our chapter on X-rays in military surgery) do not greatly encourage such operative interference. The sad result of but a few months ago is eloquent with lessons to optimistic surgery which has boasted its science above medicine. We simply point out that if an operation is impending the bullet can be found by the above impromptu technic, and if no interference is designed the same technic can at a convenient time be used minus the anæsthesia to locate the bullet without harm or disturbance to the patient, simply for the satisfaction of knowing where it is.

An X-ray examination is not a desperate resort *in extremis* as many of the public judged it to be from the Buffalo bulletins. At this late day we see in sorrowful retrospect that the question of immediate localization was of the utmost insignificance. But friends of surgery will regret that the X-ray question was not handled with candor to the public and with the decision of competent X-ray knowledge. So far as we have conversed with lay (and the same is true of medical) remarkers on the keenly disappointing case two impressions made their way into the general mind: (1) that an X-ray examination would have been so severe a shock or *ordeal* that the President could not have endured it; (2) that the bullet was not located because none of the surgeons in the case knew how to do it, and an outside expert was refused from over-confidence or prejudice or to avoid an exposure of said ignorance. The author, however, has no personal comment or criticism to make on these wide-spread impressions. He does not know the true facts. Nor does the official medical report of the case made public on October 19, 1901, appear to throw additional light on the subject. The vital surgical question on September 6th was one of non-interference and not of X-rays *per se*, and this being so it would have been well to have adopted a different attitude toward the great popular anxiety as to an X-ray diagnosis; an anxiety fostered by repeated *surgical* statements that "the X-rays would have saved Garfield." After the probe has been used it is too late to employ conservatism. X-rays then are like locking the stable door after the horse has been stolen.

Without in any respect implying that human skill could have changed the event in the stunning tragedy that closed our President's career, yet, if mistake occurred, close study of the lesson is the best way to profit by it. For this reason only we suggest that every surgeon who may be suddenly confronted with the need of caution in a fierce trial of judgment should read this verbatim extract from the Report of the Medical Department of the United States Army in the war with Spain.

"*When the probe, or one of its substitutes, is used one of the*

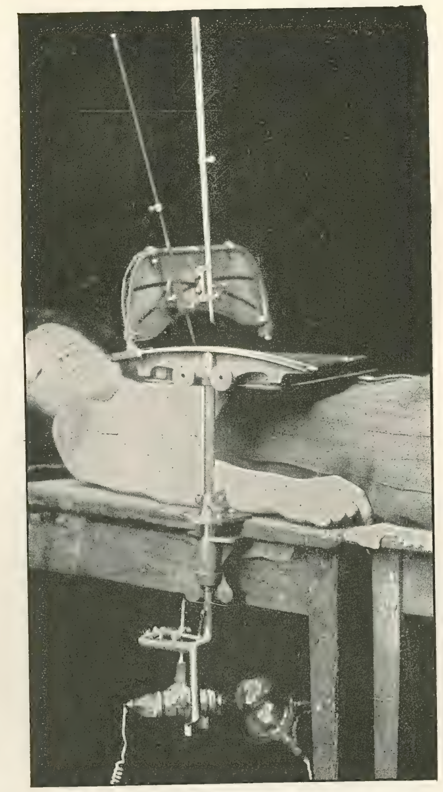


PLATE 82.—Remy Localizer. In this plate is shown a modification of the device and its position for trunk and extremities.

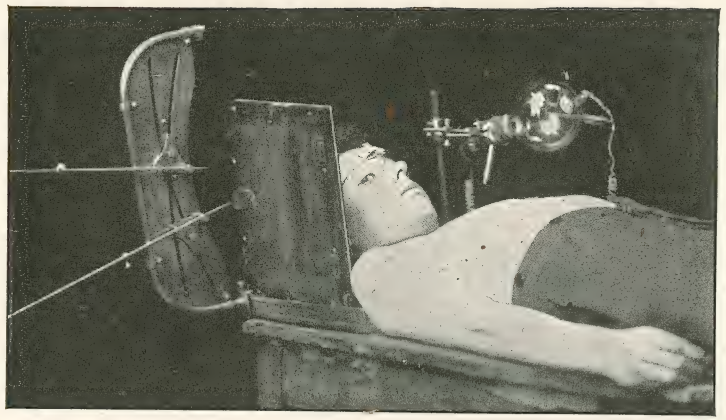


PLATE 83.—Remy Localizer. This plate illustrates another adaptation of the device and shows its position for the head. The study of these plates and description in the text will do much to make clear the identity and essential simplicity of all systems of localization. But two things are required: First, the vertical axis of the rays; second, the depth below the surface at which two converging axes in the vertical plane intersect. The foreign body is right there. The plates illustrating this Localizer are used by permission of Messrs. Rebman, Ltd., of London, and are from the Archives of the Roentgen Ray.

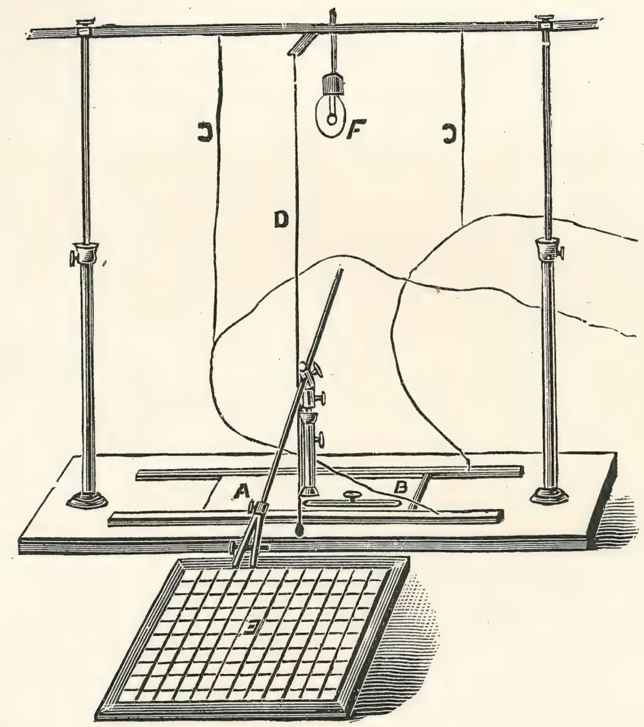


PLATE 84.—The Combined X-Ray Tube Holder, Localizer, and Stereoscopic Picture Producer, designed by Dr. Hall Edwards, is one of the most convenient tube holders, and is capable of holding the tube and conductors from the coil over any portion of the body on a bed or couch. In addition, by a few simple movements and a simple calculation, the position, distance from the surface, the size of a foreign body, can be ascertained. With it is also sent out a special plate holder, which enables the operator to produce stereoscopic pictures with ease and accuracy. This Localizer is both convenient and simple.

tenets of modern military surgery (non-interference) cannot be followed, and septic infection is made possible or probable. With the Roentgen-ray at hand the surgeon can locate a lodged missile at any time when necessity demands, and its track can be safely *left undisturbed.*

"The unreliability of the probe for locating lodged missiles is well known. With the probe it is possible to follow only a small minority of bullet tracks. The contractility of the tissues may interpose obstacles to its passage and a change of position on the part of the patient may cause such a shifting of muscular and fascial structure as to completely obstruct or alter the path made by the projectile. In fact a great majority of cases where the bullet has been located by X-rays show clearly how impossible it would have been to determine the position by means of the probe.

"But *not only is the probe unreliable, but it is a source of danger even when used with all possible aseptic and antiseptic precautions.* The experiments of LaGarde, Delorme, Habart, and Faulhaber have shown that in practically all bullet wounds some foreign matter and bacteria are carried into the wound. The number of bacteria so carried in *are not usually sufficient to produce surgical infection and subsequent inflammation and suppuration, provided the wounds are protected from further infection and are left undisturbed.*

"For undoubtedly *the factor of non-interference with the wound is of great importance.* No sooner is a traumatism inflicted than natural processes are brought into action for protection and repair. There is a local increase in vascular activity, serum is poured out, leucocytes accumulate, and the defensive factors of phagocytosis and serum bactericidal action are brought into play. That these factors may have best opportunity for action, rest and non-disturbance of the tissue are necessary.

"*Mechanical disturbance of the tissues by probe, by the finger, or by instruments will produce fresh traumatisms and cause disturbance of the defensive action going on, and these traumatisms and disturbances (however slight) will favor growth of the bacteria and add to the defensive labor required of the tissues. So that even aseptic or antiseptic operative or explorative interference may throw the scale on the side of the invading bacteria and lead to troublesome or disastrous consequences.*

"For these reasons, and in consideration of the unreliability and danger of searching for a bullet through a wound, it may be stated that such search is contraindicated except in cases where the immediate danger from the presence of the bullet is greater than the possible consequences which may arise from interference."

In the official report by the chief operator in the President's case we read: "*By the passing of a probe* it was found that the bullet had entered the abdomen."

It is useless to cite the description of the laparotomy and entire operation, which we assume to have been performed with skill, but among the editorials of the medical press on the result one states:

"*The immediate or ultimate shock succeeding* (*operation*) *is invariably very great. There is no case of recovery yet recorded after laparotomy for gunshot wound of the stomach in one over fifty years old.*"

On October 26th, the Philadelphia Medical Journal editorially remarked:

"We have pointed out from the first in these columns that the President suffered from the effect of shock—*shock caused not only by the assault, but especially by the operation.* This was inevitable. The patient went on the operating-table with a pulse of eighty-four and left it with a pulse of 124. His pulse never really rallied after the operation; it never regained anything like a satisfactory tone."

From this we may turn to the constant advice of leading military surgeons for the past two or more years and study as to what might have been the result of occlusive dressings and no surgical traumatism or shock. But here, in the fact of the shock and the pulse, we have a direct and plain indication of the powerful action of the galvanic current on the spinal centres and the heart. That this prince of remedies for shock was not brought to the President in his great need must always grieve the profession. Its physiological action has been so widely known since the classical researches of Du Bois Raymond and others that every standard text-book on materia-medica and therapeutics teaches, as do standard works on Physiology, the "nerve and muscle effects" of anelectrotonus and katalectrotonus. It is without doubt the most powerful remedy against shock. Over and over again in our own clinical experience it has quickly rallied patients from profound shock, from apparently imminent heart failure, from grave nervous depressions, collapse, etc. Think of how simple a remedy it is. Study its swift action in a crisis. Read and test how it energizes and refreshes fatigued muscle-fibres and pours new strength into exhausted nerve-centres and then ponder on a patient left without its aid. That we may all profit by these studies of this phase of the case is the earnest wish of the author.

This sad and important case has a deep interest from several standpoints, and in no spirit of controversy, but with the desire simply to place the vital surgical question before us for wise and conservative study we make the above citations. The reasons given to the public

for not locating the bullet at first with the X-rays could hardly have held at the autopsy at which "the search for the bullet exceeded the time allowed and was discontinued at the request of those in charge of the body." Still, it was not found. A glance with the fluoroscope would at least have given its approximate situation. See war records on localization of bullets by X-rays.

CHAPTER XXV

MEDICO-LEGAL RADIOGRAPHY

Useful Precautions. Liability of the Examiner. Verdict against Defective Technique. A Prosecution and a Precedent. Post-Mortem X-Ray Penetration.

The physician or surgeon without experience in law, or special knowledge of the laws of evidence, and who is called for the first time to make a radiograph for testimony in a lawsuit, must begin at the very beginning to create evidence that will possess medico-legal value. It will be impossible to set forth in this place the attitude that any particular judge may maintain, nor need the already extensive list of precedents be cited. A picture may be rejected for various reasons not connected with the medical aspect of the case, but to be admitted as competent evidence the surgeon should be prepared to show proof of *every step in the making of the picture which connects it with the case.*

By marks of identification and by a witness be able to show that the glass plate which is to be exhibited in Court was the one placed under the patient for the actual making of the radiograph. Make a written note of every detail of the technique with which the exposure was made. After the exposure every move of the plate should be connected by proof. If not developed by the surgeon care must be taken to prove its delivery to the photographer, and the photographer must guard against weakening the evidence. It may have to be proved that the plate was not *changed* or *altered* in any way, and it must come into Court with absolute proof that it is the correct and identical picture made by said surgeon of said patient at the time and place and under the exact conditions described. As a picture might be substituted, or might have been taken before or after the time at issue, the chain of primary evidence by which the surgeon proves his making of the picture and its unaltered presentation to the Court may be of very great importance.

At the time of making the picture a full fluoroscopic examination should be made and details of the findings recorded, together with the

technic of the methods employed. As it may be open to question what efficiency was possessed by the apparatus which took the picture and also what precautions were taken to insure *an accurate showing in the picture* of the condition which is at issue in the case (as, a fracture), it is important to protect these matters with proof.

The author's Register of X-Ray Penetration will prove the intensity of action during the exposure; testimony that the plate and tube were centred by the author's Position-Finder will certify to the elimination of distortion; on the plate itself the shadows of the author's Distortion Landmark will furnish unimpeachable evidence as to the degree of deviation of the axis of the rays from an exact perpendicular. The author's Divergence Chart,* which is a standard representation of the path of X-rays, will be useful in such explanations as may be called forth by counsel.

The interpretation of the testimony in the picture itself will have no value in Court unless the chain of evidence *connecting the picture with the case* is complete, and the final interpretation follows the law governing other expert evidence. As a personal precaution in the remote liability of a suit *against the surgeon for alleged damages to the patient on account of the X-ray examination* it may be a wise routine to secure a legally executed release from all responsibility, signed by the patient and duly witnessed, in advance of making the radiograph. There may be no danger or actual injury in 1,000 or 10,000 exposures, but self-protection is better than the annoyance of litigation.

A study of the following remarks by an attorney on the subject of the X-ray in law will be instructive:

"The question which propounds itself first is whether an X-ray picture may be introduced in evidence on the trial of a case as proof of the existence of the condition by it shown. Thus in an action for personal injuries may the X-ray picture of a fractured limb be put in evidence to show the existence, the nature and extent of the fracture. It is now the best opinion that *it may be so introduced* and that the jury may be permitted to inspect, provided always that the condition to be shown by the photograph is in issue or relative to the issue at bar. Furthermore, a photograph being from its nature secondary evidence merely as contra-distinguished from the best evidence, the proper foundation for its reception as evidence must be first laid by the party introducing it.

"Thus the expert must first testify to the reliability of the machine, its nature and process, the degree of exactness, etc. The reason that it is of any legal value at all in the trial of a case is the fact

* Along with this chapter should be read the sections relating to the above-mentioned special aids to accurate X-ray work.

that science and human experience have proven that the X-ray machine is capable of giving an exact reproduction if properly and scientifically used. Hence the necessity of first showing, and this carefully, that the machine and the working of it in the particular case at bar were all that was necessary for a complete effectiveness. The sufficiency of the proof first required to verify the picture is a preliminary question of fact for the judge presiding at the trial and is not open to exception. The statutes of New York State provide that in an action for personal injury, the Court, on the defendant showing certain facts by affidavit and applying therefor, may direct the plaintiff to submit to a physical examination by one or more physicians or surgeons to be designated by the Court; and such examination shall be had and made under such restrictions and directions as the Court shall deem proper. Now, then:

"*Question.*—Granted the fact that the X-ray machine has certain remotely dangerous qualities inherent in its workings, may the Court, nevertheless, order the plaintiff to subject himself to its dangers?

"*Answer.*—It will be noted that the statute referred to gives the Court power to make such restrictions and directions as it may deem proper. It will be seen, therefore, that whether or not a plaintiff must submit himself to X-ray examination, is discretionary with the Court. It could not well be argued that the plaintiff could object to the use of a thermometer, for instance, or a stethoscope in the hands of the examining physician. Why then to the use of any other instrument recognized by the medical and scientific world and necessary to the examiner in acquiring the information sought?

"No case touching the subject has yet been brought before the Courts for adjudication. It has, however, been decided that the section, so far as ordering a physical examination is concerned, does not violate any constitutional inhibition.

"*Question.*—Suppose that upon subjecting himself to the machine, if so desired by the Court, he were injured thereby; *has he redress* for his injuries, and *to whom could he look* for such redress?

"*Answer.*—In case of injury to plaintiff by use of the X-ray machine *he would have redress.* The judge ordering the examination would incur no liability. He acts merely in a judicial capacity, in which he is called upon to exercise his discretion; and he is not liable for error of judgment even though it be alleged that he acts without due care and prudence.

"The injured plaintiff's remedy must be sought *against the physician, under whose charge the instrument was at the time of the accident.* Hence, if it be charged and proved that the physician in charge of the machine did not use proper care and prudence in handling it, he must respond in damages to the one injured through such negligence."

There is an old saying that a word to the wise is sufficient, and, in view of the uncertainty of courts and juries and the fact that the examining surgeon seems to be the probable legatee of all trouble arising from mischance with the X-ray apparatus we again suggest the precautions: get a release in advance and be sure to use "approved technics," and be able to prove that such alone were used. To these precautions add a third one. *Fully advise the patient* that certain ill-effects have been known to occur from prolonged use of the X-rays, explain the nature of them, the chances of their occurrence, and see to it that in consenting to the X-ray examination he understands clearly just what he is doing. He cannot then charge that he was not informed of any liability.

In general, in regard to suits against surgeons for damages in cases of alleged X-ray injury, it would appear that ample protection may be found in following approved rules of technique, and that liability will probably result from ignoring them. *The rules of reasonably safe procedure are so absolutely simple* that no person can excuse himself for not adopting them, and proof that all due care had been exercised in this respect would probably give the surgeon the verdict. In the notable case in Paris, March, 1901, the verdict went to the plaintiff because the Court found that the radiographer had acted more like a *workman* than a medical man. The facts are thus taken briefly from the London *Lancet:*

"The Paris correspondent reports the case of a lady who prosecuted a medical radiographer for having, as she alleged, injured her by burns produced by the X-rays. She was suffering from sciatica. The leg was exposed on three occasions for forty, forty-five, and seventy-five minutes respectively. After the first two exposures, the skin became red and inflamed, yet the treatment was continued. The result was an extensive burn of the third degree. Physicians who were appointed as expert witnesses testified that the radiographer was not responsible, but they regretted, however, that no attention was paid to the signs of inflammation present at the end of the second sitting. The Court gave the full amount of damages asked for (5,000f.), finding that the radiographer had acted imprudently, *more like a workman than a medical man, and that his apparatus was defective.*"

There is a wealth of suggestion in this finding of the French Court.

In the case of Burns *vs.* Brooklyn Heights Railroad Company, November 26, 1901, a surgeon attempted to explain to the jury the alleged injury to plaintiff's right shoulder by the aid of the X-rays. Counsel for the defence objected to the X-ray pictures "on the ground that they were *shadow* pictures and incompetent and improper evidence for that reason." A long discussion as to the definition of shadows between surgeon and counsel *was followed by the admission of the evidence* and testimony was continued.

This will be a common contention of opposing counsel till the error of regarding radiographs as mere "shadowgraphs" is established among the ignorant and the laity. That the contention is unfounded will appear on *inspection* of the given picture. It is not a question of opinion but of a fact visible to the ordinary eye. Any picture of a "shadow" will exhibit its true character on sight; or, at least, will not appear to be any other kind of a picture. The image of a *shadow* may be produced on a sensitized plate in one of two ways: an object may be exposed so that light acts on the emulsion only around the outlines of the object and thus leaves an opaque shadow on the developed plate, or a camera can photograph the shadow of any object. Every one has seen such shadow-pictures, and they show for just what they are.

The common photograph—of portraits, animals, buildings, scenery, etc.—is the reduced image of the surface-appearance of the object, reflected into the camera.

The standard radiograph is the life-size image of the object made by direct transmitted light which passes through the object exposed and prints on the emulsion not only the outline, but the detail and plan of all varying densities in the structures within the surfaces of the object. It is a high-class photograph by transmitted light, comparable in qualities of true imagery with the best photography by reflected light.

Now, it is possible to so expose an object to X-rays that the feebleness of action on the emulsion will image no more than the mere outline or opaque shadow on the plate, but, if penetration and definition are attained in a true radiograph, the facts show in the picture and cannot be argued away. Therefore the decision that a given radiograph is a "mere shadow-picture" must rest on its character as such in *fact*, and the question of fact must be decided on the evident appearance of the picture submitted.

Upon the ground that skiagraphs were destined to figure largely in suits for damages after accidents and in cases of malpractice, a committee was appointed by the American Surgical Association to inquire into, and report on, *the medico-legal relations of the X-ray*. A circular letter was sent by the chairman to every member of the Association, and from the replies received conclusions were drawn which were published in eight sections in July, 1900. Many medical journals spread these conclusions far and wide, and, probably, thousands of physicians and surgeons who never did any X-ray work themselves

will base their opinions upon this public report. It was an unfortunate and premature document. Experts are raising the standard of the best radiography in a really remarkable manner as compared with average mediocre work which keeps in unprogressive channels, and doubtless the next five years will see many of the opinions of to-day as much changed as mechanical devices will change and improve. When X-rays are twenty years old instead of five the quality of "average" work may equal the best of the present time.

A Prosecution and a Precedent.—When the unexpected happens and the unpleasant surprise of litigation ensues we may be sustained by a precedent which it is a pleasure to here present in brief for the gratification of all. Dr. L. A. Perce, of California, was the victim of the prosecution and historian of the event, which we shall let him relate in his own words:

"The great interest to me of this, my first experience in injuries of X-ray, prompts me to give the full history of this case. I had been using the apparatus almost continuously for eight months before this so-called burn occurred, without the least sign of skin irritation, as well as since the injury, with still no further influence. I use a Ruhmkorff coil, capable of an eleven-inch spark. I operate it by the 110 V. current from street circuit. I control my voltage by the use of ten thirty-two candle-power incandescent lamps, placed in series, reinforced by a sliding Rheostat. This gives me ample power, and permits of a wide variation, as I may see fit to cut out or in any number of lamps.

"On January 20, 1900, one A. L. Bancroft came to me with a history of injured right shoulder of eighteen months' standing, and wanted a radiograph of the same, stating several physicians said his shoulder was dislocated, and others said it was not; he stating that when doctors disagreed, who could settle the point except the X-ray. I placed him upon the operating table, with coat, vest, and suspenders removed, with a plate under right shoulder, a good tube ten inches from his shoulder, in a five minutes exposure. When the plate was developed, I found it badly fogged. On January 24th he returned; an exposure of ten minutes given at fourteen inches distance, and no picture obtained. On January 27th he again returned and I made two exposures, at sixteen inches; one of fifteen minutes and one of twenty-three. This time a fair picture was the result, showing the true condition of shoulder-joint.

"My subject was a very large, thick chested man, weighing 220 pounds. He stated that in about two weeks a bright red spot, some three or four inches in diameter, appeared upon his right breast, above and to the right of the nipple, which later produced a sore and was hard to heal. He, also, claimed sharp pains ran down his right leg to knee; then below this point to heel, and finally to bottom of foot.

Also, his beard on the right side of his face fell out, but finally returned.

"Soon after this, he wrote me, charging me with responsibility in the matter sufficient to warrant him in demanding of me compensation to the amount of $300. This I at once refused, as I felt in no wise to blame, and not wishing to stultify myself and establish a procedure in such a case, refused to comply with his request for any remuneration whatever. Consequently, his attorney, in July, 1900, began suit against me in the Superior Court of Los Angeles County, for damages to the amount of $5,000. The case came to trial upon January 14 and 15, 1901, and after less than ten minutes deliberation by the jury, they found a verdict in my favor. Many interesting points were presented during the trial of the case, showing how necessary it would be that one operating with the X-ray should fully give their subjects to understand accidents had occurred from its use, and others may happen. I took the precaution to advise him that cases had been recorded where it had produced what was called a burn, but I had never seen one. This he corroborated himself upon the witness stand, and Judge Shaw *held this to be sufficient warning, even if such warning should be required.*

"The plaintiff introduced two witnesses as experts, who directly testified no blame could attach to me operating any kind of a machine for X-ray purposes when ordinary care was employed, such as even far less than I had employed in this case. While no protection such as aluminum plates or any intervening metallic substance was used I did carefully cover his face and shoulder with clean sterilized towels. Dr. Yoakum, one of their own expert witnesses, stated he had a number of times burned subjects, and some in less time, and others in greater or longer exposures. Dr. N. N. Morrison, Chief Surgeon of the Santa Fé Railroad, another of their witnesses, testified he, himself, had submitted to three exposures for diagnostic purposes of thirty minutes each upon succeeding days, and received a very severe burn of the whole abdomen and right hip; this, too, by a man in whom he had, and did still place, the utmost confidence in his skill and knowledge, and in no wise did he consider him, nor his apparatus, to blame. He further expressed himself as a firm believer in the accumulative theory of the ray as well as possibly the peculiar condition of the salts of the body in some subjects, making them partially susceptible to the chemical action or effects of the ray.

"Only one witness saw fit to do all in his power to fasten the blame upon the operator, and he knew nothing of the principle or character of the X-ray, but lays claim to being a skin specialist. His testimony was accepted by the jury as a huge joke, and he left the stand weaker than upon taking it. In my defence we saw fit to introduce only two witnesses, as our case was made clear by the testimony of those they expected to prove my negligence, carelessness, and unskillful application, with which they charged me in their complaint.

"In conclusion, permit me to say, that if I have been able, in defending myself in this unsought and uncalled for prosecution, to half establish the fact, that as medical men *we can use, and are willing to use, all modern and approved appliances for the purpose of diagnostic and therapeutic effect, among which the X-ray stands prominent, and feel some full degree of security granted and secured by law,* I shall feel no regrets from worry of mind nor financial consideration."

Post-Mortem X-Ray Penetration.—Among the various legends relating to the X-ray was one to the effect that the rays "would not penetrate a dead body." "Is it true?" was asked of an expert radiographer connected with a large medical college. It would seem needless to take such a report seriously in a book for the educated profession, but we are not sure that even this "X-ray fallacy" has not victimized its thousands, and it is not safe to pass it without a word. Said the operator referred to: "My experience disproves it. I have done a great deal of work with cadavers, and never had any difficulty in getting good radiographs. Some time ago I was asked to take a portable apparatus and go to a man and examine his heart and lungs. When I arrived the man was dead, but the relatives thought he was only in a trance and were afraid of burying him alive. I made the examination. The man was dead, but there was no difficulty in studying his heart and lungs."

In the historic year 1896, one of the leading experimenters in Boston made scores of radiographs showing detail that was surprising till it was learned that the subjects *were very still* during the exposures because they were parts of *cadavers.* The fact was not concealed, and the only reason for using cadavers was to study the fractures, dislocations, and traumatisms that were rapidly manufactured for the purpose of X-ray investigation.

In December, 1898, a very skilled demonstrator of anatomy in a medical college, who was also an expert radiographer, wrote of his attempt to radiograph blood-vessels, and in an elaborate article said:

"The accompanying illustrations (thirteen) were made on three dead bodies. The statement has been made that dead tissue is very much more impervious to the rays than living tissues. Accordingly I made the exposures longer. But in figure 3 is shown a controversion of the statement. The two hands there shown are the right hand of subject No. 1, and the corresponding hand of a living young woman who kindly placed her hand on the plate and allowed me to use it in comparison. Both hands were about the same thickness; the tube was so placed that it was in the same relation to both hands; and the exposure was three minutes. In photographic development both are exactly the same in clearness of definition, and no difference appears. This fact, however, was not ascertained till after all the other radiographs had been made, hence the far longer exposures than were necessary."

If any reader wishes to test the matter personally he need not be deterred by lack of a cadaver, but can secure joints and steaks from the nearest butcher shop which will serve as comparative substitutes.

CHAPTER XXVI

BINOCULAR RADIOGRAPHY

Stereoscopic Technics. The Two-Focus Exposure. The Real X-Ray Picture. Appliances Needed and Simplified Directions for Beginners. How to Examine Binocular Negatives.

Stereoscopic Radiography was first suggested in this country in March or April, 1896, and is the ideal of X-ray representation. But so slothful have American surgeons been in developing facility with the by no means difficult technic, that even in 1902 not one operator in 1,000 makes his radiographs show the part in other than a flat plane. It is difficult to explain why so superior a method should have been neglected. Perhaps because no one has led the way and employed the degree of persuasion needed to awaken the medical profession to the merits of the results.

It is certain that one view of a fine stereoscopic X-ray picture is enough to spoil the eye for the usual flat print. The view is not only a life-like relief of the part, for instance, an arm, but it is an instantaneous localizer, giving the shape, size, and position of the thing seen. The full detail of an X-ray picture cannot even be guessed at—the possibility of X-ray diagnosis cannot even be estimated—*till the stereoscope teaches it.*

One sight of the striking stereoscopic effect in contrast with a plane picture is enough to make the observer enthusiastic. Why, then, is it neglected? It supplies just what diagnosis most needs. It obviates the complaint that all the shadows of the picture are in one plane. It frustrates " distortion," for there is no " distortion " in the stereoscopic-radiograph. To say that it would clarify X-ray diagnosis a thousand per cent. would be conservative. Then why is the method not in general or even exclusive use? Why is any other method employed save that which shows what everybody wants the radiograph to show?

Is not a picture which is like looking into the part instead of at a flat and vague shadow of the part worth making? Do surgeons not want the kind of radiograph which will best and most accurately aid the diagnosis? Does no one think it worth while to even feel casual interest in the means of quadrupling the surgical value of X-rays? In theory every one yearns for new discoveries and progress: practically, one "discovery," aged now about six years, contains more potential progress in X-ray diagnosis than anything else that can be named or needed and is ignored by surgeons as if it was not going to be discovered for fifty years yet. Mention of the simple fact is instructive. Those who wish to be exceptions to the passive attitude of the majority can learn how to make stereoscopic X-ray pictures with very fair success by reading the directions in this book. A little extra trouble may be involved, but practice makes it easy and the recompense is great. The modern self-regulating tube has removed one of the former difficulties of making the two exposures alike.

Let us now see just what it is that is offered to surgical diagnosis by X-ray stereoscopy. Imagine yourself blind in one eye. You go through the world with a deficient perception of relative shapes, distances, positions, proportions, perspectives, etc., of bodies and groups of objects that you see. A radiograph taken with one focus of rays is a picture seen with one eye. It is in one flat plane without perspective and with the relative distances merged. Sense of position is feeble; form is deprived of body, and contour is only dimly suggested. A normal view with two eyes gives shape and true perspective to bodies seen. Binocular vision can estimate distances, and relative positions are correctly seen. The superiority of binocular vision over the vision of a single eye is incalculably important to the individual and a working world of one-eyed people cannot be conceived. So inferior is vision without the sense of proportion that mechanical progress would stop if the world had no inhabitants with two adjustable foci of sight.

Make an X-ray picture with two foci of sight and we at once get binocular vision effects. The one-eye, plane, proportionless, mediocre image on the film is transformed into the proportions, relations, and defined body-revealing image created by two eyes. The binocular radiograph is the stereoscopic radiograph, and, when viewed with binocular eyes in the merging-mirrors, the surgeon's vision takes the place of the Crookes tubes and successfully sees in true form, proportion, and perspective the images of the internal structures. The advantage is apparent without argument. There is no real X-ray picture other than the binocular picture, just as there is no true vision with complete functions except binocular sight. One eye does not count in scientific consideration of full vision, though it is vastly better than none to the owner, and one-focus radiography has no greater claim

to value in the surgical consideration of full two-focus radiography, though a plane picture is better than none at all.

The single-focus X-ray image limps toward a diagnosis like a paralytic with one leg; the binocular X-ray image stands out boldly on two feet and tells its story at a glance. The time lost in efforts to study out the diagnosis by plane pictures in many difficult cases would suffice to make binocular originals ten times over. The more decisive certainty of the diagnosis is an advantage that cannot be computed on a time basis. Let us now see just what tools and technic the binocular radiograph requires, and what demands it makes on the surgeon or his assistant.

A well-equipped X-ray laboratory or surgeon's exposing-room will not need a single extra tool. Appliances fitting the operator to do single-focus radiography will enable him to make binocular radiographs. The essentials are:

1. An ordinary exposing-table to hold the patient.

2. A tube-holder to hold the tube. A horizontal bar on which the tube-holder will move one and one-fourth inches to the right and left of the centre.

3. A plate-holder frame which will let the exposed plate drop down and be removed and a second plate inserted without disturbing the patient.

All else is the usual electrical and Crookes tube equipment without change. It is very desirable to have the two exposures equal in photo-chemical action on the films, and when operated by guess the variations of plain tubes made this uncertain. By the aid of a tube which will hold a regulation to which it is set, and by regulating its radiance to a desired light with the aid of the author's Penetration Gauge the element of uncertain equality in twin exposures gives place to mechanical measures of value.

A distinguished surgeon and member of the faculty of a renowned medical college, who states that he now makes *all* his radiographs for stereoscopic effects, has contributed a very illustrative article on Stereo-skiagraphy which ought to do much to lead readers to do the same thing. For its plain, sensible, informing, and educational example we quote it in great part here.

Technics.—"Stereoscopic vision is due to the fact that we have two eyes placed at a distance of about two and one-half inches apart, and each eye sees a different picture from the other. The brain coalesces the two pictures so that we see only one and that has the appearance of solidity. To produce this result in the radiograph is of the highest importance to the surgeon, and it is obtainable in the following manner:

"Place the tube vertically over the part with the target parallel to the horizontal centre of the plate on the exposing-table. The distance from the anode to the upper surface of the part may be twelve inches, or any preferred distance. Centre the plate with a plummet and fix the tube so that the focus is first one and one-fourth inches to the *right* of the plumb centre line. Then pose the tube so that *the axis-ray from the focus will pass through the spot where the plumb-ball centre touches the upper surface of the part.* Then make the exposure as usual. Next remove the negative and without moving the part slip a second plate in the same position and shift the tube one and one-fourth inches to the *left* of the plumb centre on the same horizontal line. Again turn the focus point of the anode so that a line from it to the plate will pass through the same spot on the upper surface of the part previously marked by the plummet. Then make the second exposure. Develop both negatives in the usual manner.

"These two pictures are now fac-similes of the pictures that would be seen by the two eyes at twelve inches distance, so far as respects relation and position of the bodies viewed. The central axes of the rays from the two tubes cross each other similarly to the visible threads of the familiar cross-thread localizer and thus produce the stereoscopic effect, giving visual localization.

"If a case requires immediate operation and the surgeon wishes to quickly see the position of the parts the negatives may at once, as soon as fixed, be placed in a frame with a ground-glass background, illuminated, and viewed in Wheatstone's reflecting stereoscope, which any one can make by obtaining a couple of squares of mirror four inches in size, fitted together at right angles. Then by putting the nose to the junction so that each eye looks equally into each mirror, and, placing the pictures at right angles to a line drawn through the centre of both mirrors and ten or twelve inches to the right and left, the image for each eye will be presented to it, and the single coalesced result will appear as a solid body, every part taking its proper place and relative distance. If it is desired to obtain a print it may be done by taking the wet negative just after fixing and washing, moistening a sheet of velox or other developing paper, applying it to the still wet negative and exposing it to the gas-light or other light and developed in the ordinary way. When fixed the prints may be laid on a piece of glass while still wet, and put into the stereoscope and viewed.

"If desired the pictures can be reduced to the size of the ordinary card-mount for viewing in the regular refracting stereoscope. In taking and in viewing these negatives and prints it is necessary to

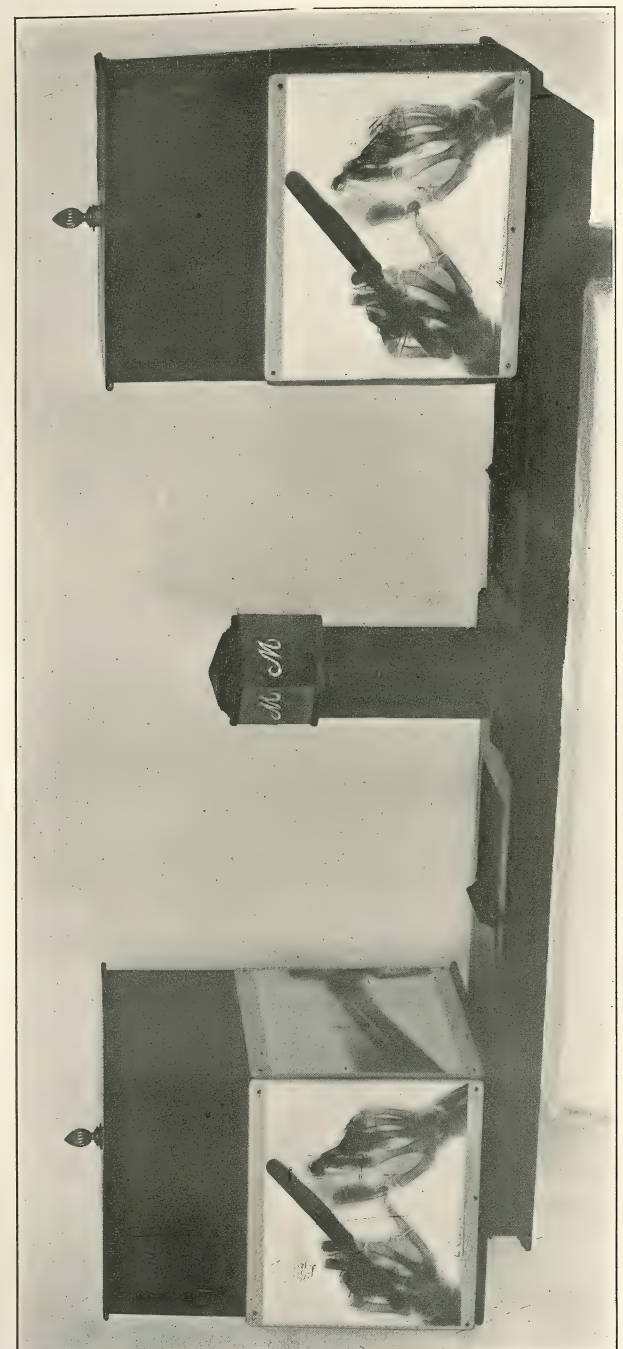


PLATE 85.—Author's Stereoscope for Examining Binocular Radiographs. A set of four pairs of prints can be tacked on the square pillars and examined in succession by turning the pillars round on their pivoted base. These pillars slide on a sledge to any focal distance from the pair of small mirrors set at right-angles on the central post and marked MM. This post slides backward and forward to any focus. For inspection level the two prints with their lines running in the same directions as shown by the two knives in the plate. Then—(See next plate).

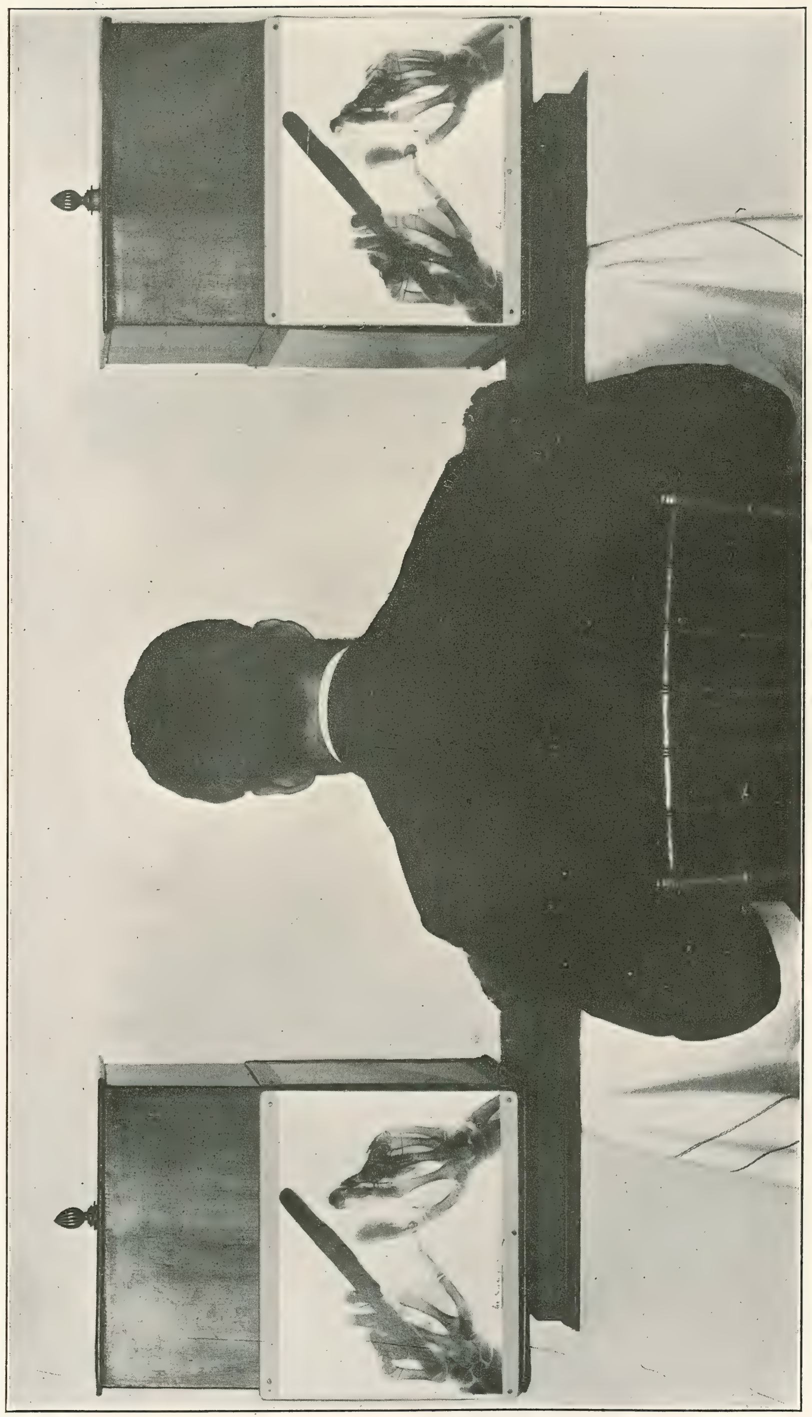


PLATE 86.—Place the stereoscope so that the light will equally fall on the right and left sides of the view, sit in front of the reflecting mirrors with the bridge of the nose engaging their angle of meeting and each eye looks squarely into one mirror. Then with each hand draw up or slide back the pillars till they are equally in focus with the eyes and both pictures appear as one. Complete the exact adjustment by sliding the post with the mirrors till the landmarks of the two pictures exactly cover each other. The view is then correct. In this photograph the author is viewing the leg containing bullet on inner sides of pillars. To view the hands cutting pear the pillars must be given a quarter turn to bring them into a position facing each other and the mirrors.

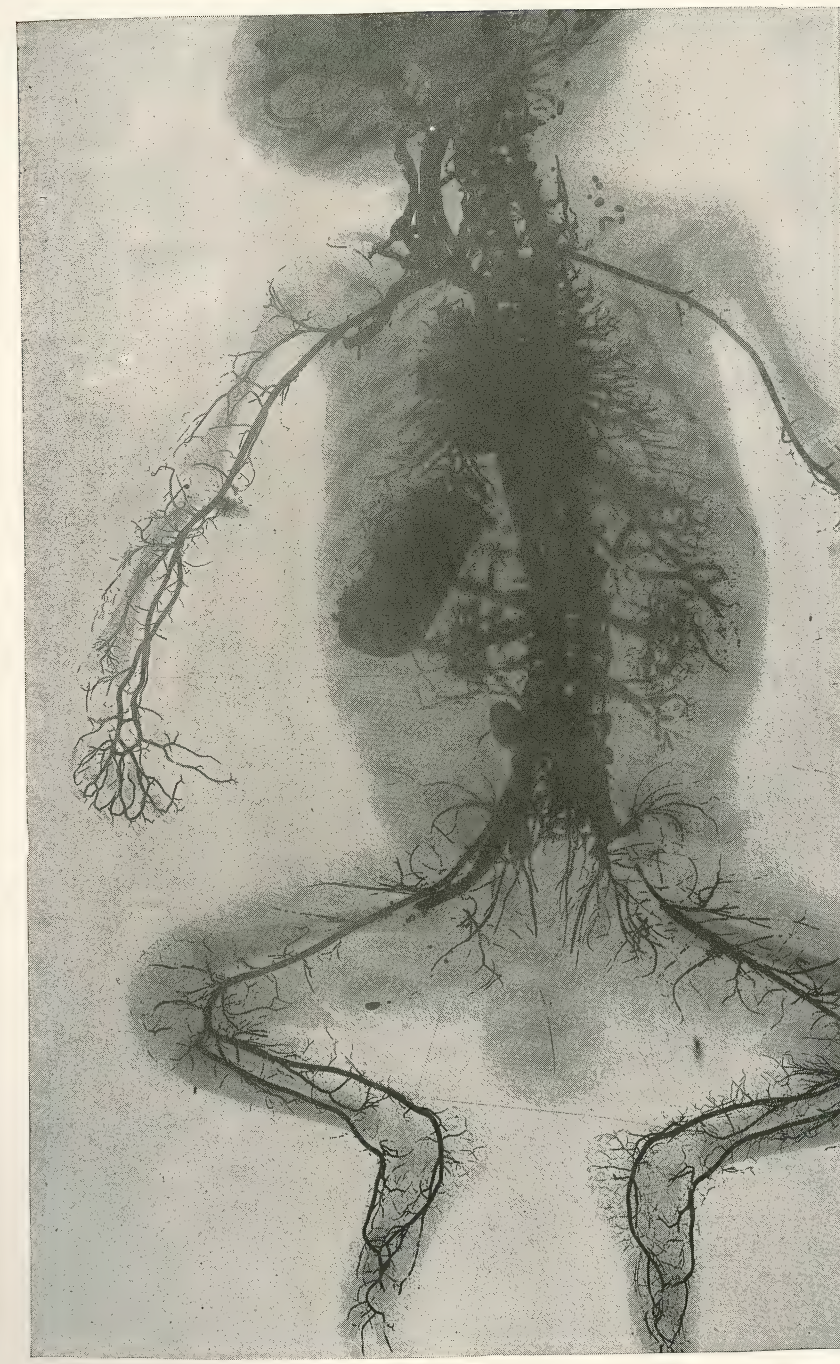


PLATE 87.—Study of the arterial system in an injected infant.

See following page for description.

Study of the Arterial System in an Injected Infant.

This subject, a still-born infant, full term, was injected with four pounds of mercury, the needle being inserted into the external circumflex branch of the femoral artery and connected by a rubber tubing to a funnel containing the mercury, which was allowed to run in of its own weight under a pressure of a sufficient column. The injection was watched through the fluoroscope. The exposure was 20 minutes with the anode 24 inches above the centre of the plate, using a ten-inch coil. The detail preserved even in the reduced cut is well worth a great deal of careful comparison with the reader's own work if he is a beginner. It is by comparison of many radiographs that skill in interpretation can best be acquired. Negatives that look very nearly blank to the non-medical *professional* photographer accustomed to portraits and interior work will tell much more of a story to him who can read the shadows than does the microscope in many cases. A pair of stereoscopic pictures would show this detail to far better advantage. (Rebman, Ltd.)

be particular in the various processes of copying and printing to bear in mind the changes of reversal due to the printing or copying. One great advantage of this stereoscopic method to the surgeon is that by simply shifting the right picture to the left and the left picture to the right after the first view he can reverse the view and thus inspect the same body *from both front and back*, and be better able to judge of the relative distances and positions of the objects."

Frame for Plate.—A necessary device in the taking of stereoscopic radiographs is a means of exchanging plates without the slightest disturbance of the part which is being exposed. Make a substantial wooden frame large enough to admit the plate. It may be about two inches thick. Across the top of it, stretched like a drum-head, cover a light-proof parchment. Make the floor movable, and with small blocks so as to receive the plate always in one situation. When the plate is inserted have the floor lift by a lever so as to raise the plate to close contact with the parchment. The arm or part resting over the parchment remains stationary after the first exposure while the floor is lowered, the first plate removed, the second plate inserted, and the floor raised again and the second exposure made. If a cross of fine cotton-wrapped wires is tightly stretched over the centre of the parchment, it divides the plate into four quadrants in the radiograph with the centre at the point of intersection, and over this point the tube is focussed with a plumb-line. If the wrapping of these wires is freshly wet with marking ink the impress will mark the skin of the patient coinciding with the shadow of the wires on the negative. If these markings are not desired in a given case, omit the cross wires.

The Tube-Carrier.—In making a stereoscopic radiograph it is necessary to shift the tube in a special manner, and this requires a horizontal bar parallel with the cross-wire marking the centre of the plate, and fitted to two uprights which are adjustable over the patient. This bar is fitted with a spirit-level, a tube-holder, a centimetre scale, and adjustable stops. A scale runs from zero in the centre to each side. The cross-bar can be raised or lowered as desired on the upright posts and the sliding tube-holder can be shifted to any part of the scale. The displacement of the tube for a stereoscopic picture is usually three centimetres on each side of the centre. The displacement must always be horizontal to the plate and parallel with the equator of the plate.

Stereoscopic Exposing Device.—An apparatus for taking stereoscopic radiographs has thus been described by Gregory:

"This apparatus was devised to give with ease and celerity the actual position of a foreign body or injury to the bones of hands or feet, etc., by viewing a picture taken stereoscopically on a single plate.

It consists of a base-board on which is placed a platform of card-board eleven inches in length. This is supported on each of its longest sides by wooden strips a half inch thick, thus forming a sort of tunnel through which a sliding carrier fourteen inches long of thin wood can be pushed easily from side to side. This has stops on it to keep the plate in position centrally. The card-board is protected by tin plate for four inches at each end, thus leaving three inches clear in the centre. In this portion five straight cuts are made partly through the board in which are imbedded fine No. 36 copper wires a half inch apart. In a line with the centre wire is placed a wooden pillar with a joint level with the top surface of the card. This has adjusting screws so as to limit the side screen of the pillar to the width of the eyes at about ten inches above the joints. There are holes in the pillar to take corks as tube-holders so as to vary the distance from the object.

"In use, the focus-tube is placed in position so that when the pillar is vertical the platinum plate is square with the centre of the three inches clear space on the platform of the part to be taken. The plate is put in its place on the slide and shifted to the left so that the ends of the slide and the platform coincide, and the pillar is inclined to the right. The current is turned on for the requisite time, and stopped, the position of the slide and the pillar reversed and another exposure made. The axis of the rays is thus kept pointing to the centre of the platform. We shall thus obtain on the plate images of the bones, etc., and also of the wires which serve as a base-line as seen with the right and left eyes, and all stand out in relief in the stereoscope. The apparatus may be made much larger to take thicker bodies and larger plates, to be used with a reflecting stereoscope. The carrier can, of course, be made as a dark slide. One of the difficulties experienced is to give the two exposures the same density and clearness in the negative, but expert operators can succeed well enough for practical purposes."

Examining Stereoscopic Negatives.—When the surgeon has read exactly how to make a stereoscopic radiograph of a part and has successfully put the instruction into practice, what will he do with the finished pictures? As the ordinary parlor stereoscope is useless, how shall he examine them?

It is possible to so train the eyes of an expert that stereoscopic vision becomes an acquired faculty of sight; but while so few possess this knack of visual focus the aid of a pair of mirrors solves the problem. Take two squares of ordinary mirror glass about five inches wide and long, and join them at one edge with an adhesive muslin hinge so that they will fold shut or open to a right angle. Set this piece on a table in front of the eyes so that the angle faces the median line of the nose, and the mirrors diverge equally at the sides. Hold the pair of pictures so that each will reflect in its own mirror. Adjust them to distance and position so that the two finally register as one.

For exhibition of stereoscopic pictures or for more complete examinations by the surgeon a frame for the mirrors and means of supporting the pictures is useful. Such a frame may be finished in various ways. The side pieces for the pictures may be flat, or made to take one or a series of pictures. The frame shown in the photograph was brought from London by the author in 1898, and was made to exhibit four pairs of pictures in a series by simply turning round the square pillars at the ends. The pictures may be held up against the sides by the examiner, and rapid inspection made of any number of pictures; or, to show a class or for general display a set of four pairs is tacked on the sides and examined in turn by revolving the pillars on their pivoted base. (See Plates No. 85 and 86.)

To inspect a given pair of stereoscopic pictures with this appliance after they have been placed in equal positions on the opposite sides of the frame move the apparatus so that an equal light will fall on each picture. It may face a window, or, an electric-light just behind and above the examiner's head is efficient. Now, with each hand draw up the side pillars till they approach to an equal distance from the mirrors at a point where both nearly register in line. Then slide backward or forward the post holding the mirrors till they focus to suit the eyes. When both adjustments are complete the two pictures will show as one and the shadows will no longer appear flat, but will show the full rounded contour of the part.

CHAPTER XXVII

THE STANDARDIZATION OF SCIENTIFIC X-RAY TECHNICS

The Problems Presented.

The importance of placing X-ray work upon a basis of uniformity is patent to every one. When Chairman of Committee on Standards of the Roentgen Society of the United States, the author presented a list of requirements, with a request to members for suggestions. In the Spring of 1901, this list was personally mailed to between 200 and 300 special X-ray laboratories, hospitals, and prominent private operators. It at once appeared to be the universal opinion that nothing about X-ray work could be standardized or formulated upon a methodical basis. This view was a striking comment upon the attitude of the medical profession toward methods of precision. While convenience might well be assisted by an agreement among makers upon various mechanical details of apparatus, yet the basic problems presented to aid uniformity in results and eliminate careless and haphazard methods commonly employed, are mainly:

1. The correct position of the tube in relation to the photographic plate and patient. The author's Position-Finder settles this problem.

2. Immobilization of the part after it is correctly placed for the exposure. Reasonable ingenuity can accomplish this except as to the heart.

3. A standard distance of the tube from the film. A set of correct distances for thin and thick parts of the body with reference to the least distortion within the diagnostic field, is automatically supplied the operator by the author's Divergence Chart and a standard distance for a standard exposure can be adopted.

4. A means of knowing the "defining efficiency" of the radiance in order to determine the time required for the exposure. The author's Penetration Gauge enables this to be done at the time of the exposure, with almost no complication or delay.

5. A system of landmarks to be printed on the plate to aid identification, localization, interpretation, and prove the position and distance of the tube during the exposure. How well these are supplied may be judged from our chapter on Landmarks.

6. The photographic problem presents the first and final difficulty.

However great may be the variation in emulsions and in developing processes, yet uniform adoption of similar X-ray plates (the best obtainable at a given time) and skilled treatment of the negative, would certainly permit a great advance on the average work of the past four years. It is not, however, the author's purpose in this writing to attempt more than the instruction of the beginner in the essential details of X-ray work so as to best improve his individual results. The formulation of standards of technique is properly the function of the Roentgen Societies of the World. The adoption of certain fundamental standards would not, however, require the individual operator to do all his work by arbitrary methods. The standards would afford *means of comparison*, of *aiming at the best results*, of *going into court in a medico-legal case supported by the highest usage*, and *protection* against charges of inaccuracy, injury, or other results alleged to be due to defective technique or malpractice on the part of the operator. The surgeon who conformed to the rules of technique officially agreed upon by the leading Roentgen Societies would be greatly fortified in his defence of a suit incited by a speculative lawyer.

The replies received by the author in respect to the formulation of standards showed that none of the profession grasped the true significance of his purpose. One and all seemed to regard the suggestion as the pursuit of a fanciful ideal which could bear no relation whatever to practical work. A few years more may advance the average of X-ray education, and the pioneer efforts of the author, abandoned for want of co-operation, may yet bear fruit.

CHAPTER XXVIII

"X-RAY BURNS"

GENERAL INFORMATION. TREATMENT. CASES. RISK OF PATIENT IN SKILLED X-RAY EXAMINATIONS. SIMILAR EFFECTS WITHOUT X-RAYS.

THE discharges from an X-ray tube of *high* vacuum and over ten inches from tissues have little tendency to set up dermatitis. In ordinary radiographic or fluoroscopic work for the purposes of *diagnosis* the time required to develop even traces of action on the tissues is from ten to fifty times the length of modern exposures. The "risk" of a proper X-ray *examination* is infinitely less than the readily accepted risks of anæsthesia. It is less than the risk of a trolley ride.

A tube of any vacuum held much nearer the tissues than is the rule in radiographic technics but which has been common in X-ray *therapy*—say from eight down to two inches from the tube-wall—will cause tissue changes which slowly pass through stages of irritation, inflammation, ulceration, and necrosis; depending on the nearness of the tube, the amount of current, the excess of exposure-time, and the degree of impaired vitality of the tissues. This dermatitis may be developed to severe and slow-healing effects by cumulative exposures, or may be as mild from single long exposures as a brief sunburn.

In 1896-97 about 100 cases of all degrees were reported. Then with improved apparatus they became (in diagnosis) practically obsolete. Out of several million radiographic exposures scarce any "burns" occurred. But X-ray *therapy* was investigating their actions and began to cause them purposely as a counter-irritant in certain skin diseases. Therapists resumed what diagnosticians had discarded, to wit: low tubes, short distances, and long exposures. For a time dermatitis was thought to be essential to a "cure." Then reports of even better results were made by men who sought carefully to avoid the dermatitis effect. Medium and high tubes, moderate exposures of not over fifteen minutes, and distances of from six to ten inches enabled operators to treat patients with all the benefits and none of the annoyances of earlier methods which aimed at an inflammatory reaction as a road to cure. The use of metallic coverings on the part with

holes cut to fit the lesion also gave general protection from currents that irritated, but with other doses of current no protection was needed and no precautions were required to prevent dermatitis. The heavier the current the greater its capacity to set up dermatitis with a given tube and distance. This rule applies to both Static and Coil currents.

The parts most susceptible to X-ray dermatitis are those thinly covered with muscle, and those having growths of hair. Bony prominences where the nutrition of the soft parts is poor and the surface has the dry resistance of a hairy skin have suffered most. The back of the hand, the eyelids, and scalp are typical examples. The dry resistance of the hair and nails renders them a prey to the irritant action of discharges which pass smoothly through tissues of better conductivity. Impaired vitality or a local lesion may furnish a focus of inflammatory action. *Exactly similar dermatitis has been reported when no X-rays were generated in the tube, and also when no tube at all was connected.* But no case has ever occurred when no electric discharge was present. Painless at first and with slow development varying from three to six or ten days after the initial exposure the deeper lesions have been slow to heal and have acted much like some galvanic burns. The conditions under which they have most appeared have been:

1. Low tubes.
2. Heavy currents.
3. Long exposures. Or, frequently repeated exposures with cumulative effects.
4. Tissues near to tube-wall.
5. Susceptibility of the tissues. (A previous irritability.)

When it is desired to avoid dermatitis the conditions to be observed in diagnosis are:

Medium or high vacuum tubes.

Twelve or more inches between the tube-wall and the nearest tissues.

Short exposures. (Less than fifteen minutes; usually under five minutes.)

These simple measures insure exemption from accidental dermatitis. The action from several short exposures closely following each other is nearly equivalent to that of one excessive exposure. Therefore do not repeat long exposures after a first radiographic failure in less than a week. Sufficient account of the character of different degrees and stages of this low grade of inflammation is contained in our therapeutic reports and needs no further description here.

Treatment.—Preventive treatment, in addition to the employment of approved technics, is usually interposing a grounded sheet of some thin metal called a protecting screen, as described in our section on "screens." Or, to protect their hands men who do continuous work with X-rays wear gloves and keep the hands as much out of the field as possible. As dry or hair-covered skin loses much of its resisting quality when wet with a hot solution of bicarbonate of soda; it is recommended to lay a wet cloth or towel smoothly over the part during the radiographic exposure when irritation is feared. The part itself may first be shampooed, and the towel then wet in the soda solution the same as for a galvanic application and laid on the skin.

For the simple erythema, which may develop after considerable exposure and gives warning to halt before deeper effects are caused, a simple emollient to keep the skin soft and a cessation of X-ray work will usually suffice for treatment. Mr. Kinraide, however, finds the following method immediately abortive: At the first sign of erythema, say on the operator's hands, fill two small pails nearly full with water as hot as can be borne. Add a table-spoonful of bicarbonate of soda to each, immerse a hand in each pail, and let them soak in the alkaline solution till the water cools, or about twenty minutes. This has sufficed to at once relieve the effects. For the dry atrophic state into which the fingers and nails of workers sometime get the negative galvanic current should, on theoretical grounds, do much to restore normal nutrition, but the author has had no case occur in his own practice and hence cannot speak from actual test. The negative galvanic current in a very small amperage is a powerful stimulant of healing processes.

For accidental dermatitis occurring in patients there is no specific treatment, but such indications as appear in the given case at the time seen must direct the care. The experience of a number of surgeons who have encountered the lesion in its more severe forms will instruct us:

"The X-ray dermatitis is very painful in some of its degrees and heals with difficulty. The slight forms are affected by applications of dilute lead-water lotion. Among the various remedies that have exerted some influence in the severer forms are zinc oxide, ichthyol, and boric-acid ointment with ten per cent. of lanoline. The pain of the severest form is relieved by an ointment containing fifteen grains of antipyrine to the ounce." (LEONARD.)

"In a severe eczema of long standing resulting from X-rays, in which other remedies had failed, good results were obtained from applications of nitrate of silver in strong solution." (DUNN.)

Butler reports having used on one incipient case a fifty per cent. ichthyol and lanoline ointment, with boric-acid. Also a boric-acid

eye-wash for the conjunctiva which was involved. In another case which had blistered the ointment did not suffice. The patient began to suffer considerably and orthoform was used locally. The other treatment was about the same as is used in other forms of ulceration, peroxide of hydrogen, balsam of Peru, Castor oil, and various drying powders, which last seemed to give the most relief. The patient tried pretty much every form of dressing.

Another more severe case with burning, itching pain was first treated with I and L ointment; after that by drying powders, covered with gauze and rubber-tissue. Moist dressings of gauze wrung out in hot carbolized solutions and covered with rubber-tissues, cotton, bandages were soon substituted. The wound seemed to be healing rapidly. Orthoform succeeded better than other things to control the pain. The patient was then away two months, using various ointments. On his return the surface of the ulcer was covered with the thick, dry, leather-like, necrotic membrane that seems to be associated with the final stage of burns of this degree. Hot applications and poultices failed to soften it. The following ointment was then applied daily, and almost immediately began to soften up the membrane.

℞ Lead Plaster	6	drachms.
Cosmolin	2	"
Salicylic Acid	10	grains.

Each day some of the membrane of softened necrotic-tissue was trimmed away. It was difficult at times to tell how deeply it could be cut without pain to the patient, as occasionally, tissue that was black and apparently dead would bleed and cause great pain. The ointment seemed to give great relief. In a month and a half the membrane was about gone, and hot moist dressings were resumed. With a week's preliminary treatment with the hot normal salt poultice, eight skin grafts were made on the spots which promised best results. This was repeated in five days, with a total of seventeen grafts. The Reverdin Method was employed. The only dressing was the normal salt poultice, and over this a hot-water bag, which is a great help in skin-grafting, as it furnishes the very needful heat, and also makes slight pressure at the same time. Fifteen of the seventeen grafts "took" and seemed, as they often do, to act as a stimulus to the healing of the skin from the edges. The patient recovered entirely. After citing ten cases in all the author concludes:

"Proper treatment hastens recovery considerably, contrary to statement of Moullin and others. Burns of the first degree are benefited by the continual application of ointments, especially those having a lanoline base. Various ointments and drying powders increase the amount and thickness of necrotic membrane in burns of the third degree. Hot, moist, mildly antiseptic dressings, used early in burns of second and third degree, help to limit the extent of ulceration, and used later, help to hasten the process of repair. Skin-grafting at the proper time is indicated, contrary to the teachings of some."

Another author remarks: "There may be lancinating, peculiar pains, a sensation of heat or cold, prickling, sometimes anæsthesia and analgesia. The implicated areas may remain hyperæsthetic for a length of time with a diffuse erythema or dermatitis. The process begins as a red spot with circumscribed macules or vesicles, vesico-pustule, or a pustule, accompanied by itching and burning. They rapidly develop and increase in size. The destruction of tissue is sometimes superficial, but more often through the entire cutis and even subcutaneous connective-tissue, forming an ulcer. The tissues and effused grayish necrotic matter about the focus of inflammation perish; the peripheral areas become vascularized and are finally converted into granulation. The capillary loops at the base of the ulcer may be red, bleed easily, and are very sensitive. A crust may form and be removed; the lesion may remain stationary. It takes time before a surface of healthy granulation is established. We may make three clinical subdivisions:

"1. Simple superficial inflammation of the skin.

"2. The acute attack upon the skin and deeper tissues, producing a partial effect upon the peripheral extremities of the vaso-motors and spasmodic contraction of the blood-vessels, followed by immediate relaxation and renewed nutrition of the cells. Antiseptic treatment indicated.

"3. Sequelæ of an acute attack, with much destruction of the skin and tissues. In this, with more ulceration, there is more pain and tenderness, superadded to an increase of unhealthy granulation. It will not yield to any dressing. Cleanliness, local rest, and later, massage twice daily, are of inestimable value in maintaining good circulation.

"Under the local-rest treatment an acute attack will in due course begin to subside. The pain, tenderness, and redness will become less. If at this period the lesion be touched it will be found that, although the ulcer looks better, this is not the case with the tenderness. Some spots will be found which are not in the least tender; others where the tenderness is extreme and seems to be linear along the site of a nerve-trunk distributed to the periphery affected. Injured parts are more susceptible than normal tissues." (Jicinsky.)

These cases of severe lesions are now rare and have not come into the author's practice, but from a resumé of the reported indications it would seem that selected applications of electricity could well meet them all, combined with ordinary surgical care. The relief of pain, sedation, arrest of suppuration, improvement of the local blood supply, promotion of healthy granulation, all come well within the simplest resources of scientific electro-therapeutics, and if applied early should also act as a prophylaxis. Theoretically the remedy fits if dosed according to the indications. As said before, the galvanic current in small dosage with the negative pole is one of the most energetic promoters of nutrition in atrophic states, and static electricity can also be so administered and dosed as to remove pain, allay irritation, heal ulceration, improve the local blood supply, start up nutrition, and greatly stimulate repair. In a mild case of pigmentation, superficial inflammation of the skin with itching, pains, stiffness of the skin, drawing tightness, etc., apply a cooling and sedative negative static breeze from a fine brass-point electrode on the bare surface at close range. It will remove the pains, stiffness, and irritation almost at once. The effect is excellent and can be repeated as necessary. When the surface is nearly convalescent a few fine sparks will quicken recovery. The sinusoidal current has also been employed with excellent results in suitable conditions and has great value.

As it is superfluous to repeat here any of the extensively described cases published in early medical journals we may illustrate enough for the purposes of practical information by citing the only two cases which occurred during our war with Spain. They are taken verbatim from the official report.

"Case 1.—Severe X-ray burn by coil. Thomas McKenna, Company C, Sixth U. S. Infantry, gunshot fracture of upper third of right humerus at Santiago; excision made of upper part of humerus. About five months later an attempt was made to radiograph the shoulder to ascertain the condition of the bone. An exposure of twenty minutes was made with a coil actuated with dynamo-current, with a low tube ten inches from the shoulder. No result. A second and third trial was made on successive days, but the tube was so poor that no satisfactory picture could then be obtained with it. Six days after the last exposure slight redness of the skin appeared on the chest and shoulder. The erythema increased, and two days later small blebs appeared. These broke, and small ulcers formed which gradually spread and coalesced. The tissue necrosis deepened and extended, and was accompanied by marked pain and hyperæsthesia. The inflammatory action continued until the lesion covered nearly the whole right breast. Treatment of various kinds was tried, but the greatest benefit was derived from continuous applications of lead and opium lotion. The burn showed no signs of healing for four months. After that time it gradually grew better, but so slowly that the healing process was not complete till eleven months after the first appearance of the lesion.

"Case 2.—Slight X-ray burn with the Static machine. Walter C. Booth, radiograph attempted to discover calculus suspected in pelvis of left kidney. Exposures of twenty-five minutes each were made on three occasions two days apart. Five days after the last exposure an erythematous spot appeared on the left side of the abdomen. This gradually became pronounced in color and spread. There was hyperæsthesia of the part, but no ulceration occurred, and the irritation disappeared in about ten days leaving no sign."

Risk of the Patient in Skilled X-Ray Examinations.—To the more recent graduate whose X-ray experience is but beginning and does not recall the discussions of 1896-97 the question may occur as to which type of electrical apparatus is most liable to cause irritation; and also as to how much the whole risk amounts to anyway. Let us see.

As to the question of apparatus: In proportion to the relative number of each employed the few accidents have been impartially divided between them all. For instance, the total number of "X-ray burns" reported during the Spanish-American War from the seventeen equipments of the army was two—one from a coil and one from a Static machine. "In each the exposure was prolonged and frequently repeated, and the tube was refractory." But the causative factor is not so much the kind of current used as the bringing of the tissues into *close range* of an "*over-dose*" of a "*heavy*" current (of *any type*) discharged through any tube. Passing the static current through Leyden jars gives it more of the quality of a heavy coil current, but the state of the tube seems to influence the cause of dermatitis more than the current *per se*. Yet the tube has no such influence unless the part is exposed near enough to be within the field of this action, and beyond ten inches the action rarely occurs with any tube or any current.

Now as to the general liability of the patient exposed: During the first five years following Roentgen's discovery we may estimate that fully 10,000,000 X-ray examinations were made throughout the world. Perhaps the real number is double this. It can only be estimated. But out of this great total the entire number of "burns" reported in diagnostic exposures have hardly been 200. The serious lesions have not numbered 100. Among the many who make regular use of the X-ray and have reported that in 2,000, or 3,000, or more, examinations they have had no case of injury to a single patient it will be sufficient to quote two surgeons.

"I exposed a feeble child five years old to the rays for forty-five minutes at a distance of sixteen inches. In the months of December and January nearly 600 eyes, representing every nature of disease

causing blindness, were exposed to the X-rays. No ill-effects were noted in any case, and many were exposed at six inches for ten minutes.

"Exposure was made for twenty minutes at twelve inches distance upon women in the first, second, and third months of pregnancy with no observable effects, and the maternities at regular term were normal.

"A hen laying eggs was exposed to X-rays several times at six inches, for fifteen minutes at a time. The hen set on nine of these eggs. During incubation the hen and eggs were rayed for fifteen minutes at six inches from the tube. All the eggs hatched and the chicks appeared normal.

"Any substance capable of shielding the body from the electrical actions but pervious to the X-rays and not interfering in the least with their free passage through the body prevents injury and provides a reason for the conclusion that the X-ray itself has no harmful properties. With all that has been written in the lay press, medical journals, and scientific publications, I am unable to find a rational conclusion for the belief that the rays called X-rays ever injured in any instance human tissues." (Editor *American X-Ray Journal.*)

"Since Roentgen pointed out that non-conductors when traversed by the X-light may become conductors, the task of ruling out the electrical effect is not a light one. What I do wish to call to the attention of your readers is this: that *practically*, in careful hands, there is no danger from the use of the X-ray *to the patient*, and very little to the operator. The facts on which I make this statement are these: That in the last five years about 8,000 exposures in over 3,000 cases have been made at the Massachusetts General Hospital *without a single case of X-ray dermatitis in the patient.* That at the Children's Hospital, in the last eighteen months, we have made about 1,000 exposures in over 300 cases, without a *single case of dermatitis in the patient.* That in the last five years, in my private practice, I have made nearly 1,000 exposures without a single case of dermatitis in the patient. The sum total is about 10,000 exposures in 4,000 cases without one case of loss of hair or burn of the skin.

"As far as danger to the operator goes, there is no question that a serious dermatitis extending into the deeper layers may be set up. At times my own hands have had the typical appearances of a slight grade of this form of burn, but they have never been excoriated nor cracked, nor so severe that I could not go through the ordinary permanganate preparation for surgical operations. I attribute this freedom from trouble to my habit of never exposing myself near the tube if I can possibly help it. I take no other precautions. One severe case of maiming dermatitis I have seen, in a gentlemen whose enthusiasm outweighed his prudence, but the value of whose work has almost compensated for the sacrifice.

"I seek the opportunity of mentioning these facts in your columns because I believe that the comparatively small number of unfortunate cases which have been published have circulated much farther than the immense number of fortunate cases, and have given the profession the idea that the process is a dangerous one *to the patient.* The fact that the X-ray is in daily use in the large hospitals without harmful results should be put in blacker type than the rare exception.

"E. A. Codman, M.D.,
"*Surgeon to Out Patients, Massachusetts General Hospital;*
"*Skiagrapher to the Children's Hospital.*"

The two factors, skill and caution, always of value to the surgeon, will reduce the liability of accident to a minimum in each and every use to which the X-ray can rationally be put. In almost all cases of X-ray burn reported the tube has been nearer than eight inches from the tissues, often only three inches, sometimes less than one inch. Some of the early injurious exposures were from one to three hours. With good apparatus and technic no short exposure at even the shortest radiographic distance has set up any degree of dermatitis. In skilled and careful hands it may be claimed that *a tube is practically as little danger to a patient as a camera.* To make this true in fact should be the aim of all physicians.

Similar Effects without X-Rays.—*The American X-Ray Journal* in August, 1897, published an article on "X-Ray Injuries," by Dr. Scott, of Cleveland, O., which at the time was the most careful resumé of the subject that had been made by an impartial and earnest investigator. In directing particular attention to this article the Editor mentioned certain tests of his own which had caused the same dermatitis *without* X-rays. He said:

"I made a chain of twelve Grecian sponges tied together with cotton string. The first sponge was united to a No. 32 wire six feet long. The other end of the wire was hooked to an exposed electrode of a Crookes tube incapable of generating X-rays. The current was from a High-Frequency coil excited from the alternating street current. In the test the current divided just as it would do in a live tube and passed with considerable resistance to the twelfth sponge, which was (by the aid of an insulating handle) brushed over and near the thigh of a paralytic. Tests resulted as follows.

"After a time sensation was perceptible, and later a dermatitis appeared. The experiment was repeated with a tube giving X-rays, with the same result.

"The same result is obtained if the wire is coiled about the tube.

"If the skin is exposed to any point of the wire connecting the strand with the Crookes tube the result is the same.

"If the skin is exposed to the tube while an electric current passes the effect is the same, and it is not modified by the direction of the anode."

"At a recent meeting of the Vienna Society of Physicians, Dr. Schiff and Dr. Freund reported an interesting action of high-tension currents on the skin. According to the authors (says the *Lancet*), when the hairy skin is exposed for twenty minutes to the silent discharge of the negative pole of a powerful Ruhmkorff coil, such as is used for the production of the Roentgen rays, the hairs commence to fall out, the hair bulbs become atrophied after the third exposure, and some days later the portion of the skin which had been exposed becomes perfectly bald. The hair follicles become red and inflamed after the first two exposures. These observations seem to prove that depilation can be produced by the action of high-tension currents, and that the depilatory effect of exposure to the Roentgen rays may be accounted for in this way."—*Electrical Review*, 1901.

At the meeting of the Roentgen Society in December, 1900, Mr. Kinraide stated that he had personally suffered all the effects of a bad "X-ray burn" from making a series of coil experiments with a very powerful coil without any tube or any X-ray apparatus whatever in use. The author can produce very similar "burns," varying from slight erythema to deep ulcers by passing any considerable static current to the tissues through a sufficient dry resistance. Many seem to be unaware that this can be done.

Conjunctivitis and Incipient Retinitis from X-Rays.—Operators subject to long-continued exposures suffer some from irritability of the eyes which can develop into inflammation with sufficiently intense cause. Sherer reported such a case in a physician who had been daily exposed to the action of X-rays for three years and a half. He first suffered from photophobia and eye-fatigue. Later conjunctivitis developed. The histories of several similar cases have been given. Read also our report of case exposed to intense arc-light in section on Phototherapy. The obvious protection for operators using X-rays and finding trouble with their eyes is the same as that employed in phototherapy. The chemical rays are nearly stopped by plain clear white glass, and the physician who does not wear glasses for visual defects can avoid irritation during X-ray work by wearing a pair of large plain glasses without focus.

Note.—The author prepared a full description of the various theories regarding X-ray burns; but, as some fifty pages of text were thus taken from more valuable matter, it was deemed best to omit the further discussion of burns.

CHAPTER XXIX

X-RAYS AND FRACTURES

General Studies. Differential Diagnosis.

It was from the first obvious that X-rays ought to impart information about fractures, but owing to reliance upon a *plane* shadow taken by transmitted light too often *without traversing the fracture line*, the great bulk of negatives made by non-experts (whose name for the first five years of radiography was legion) the impression got abroad that X-ray information was not reliable. On the other hand, experts, accurate though few, aligned the part in the essential mechanical relation to the axis of the rays, adjusted the factors of the exposure, and reported results that at once awoke skepticism.

Owing to the general need of knowing what aid in diagnosis to expect from X-rays, we shall carefully review the best opinions available. In studying these reports we must bear in mind that they refer solely to examinations made with *a single focus*, and that such work is but the infancy of the fuller development of technical methods held out to the profession in stereoscopic effects. However slow it may come, the day will come when X-ray examination without *binocular perspective and form* will be deemed as unworkmanlike as auscultation of the lungs through an overcoat. Still, we must here consider the routine of to-day.

A new treatise devoted exclusively to fractures thus summarizes the application of ordinary radiography to this particular branch of work:

"The greatest usefulness of the rays thus far is in the recognition of fractures. With their aid accuracy takes the place of ignorance and doubt, and painful manipulations cease to be necessary for diagnosis. Nor do they merely confirm knowledge already gained. Even the most skilled experts in fractures are unable to deny that owing to swelling of the soft parts and obscurity of symptoms there are many bone injuries the true character of which could not formerly be discovered by an examination. The number of cases of fracture formerly mistaken for sprains, contusions, or displacement was enormous. It is in such cases that a simple glance with the fluoroscope

Plate 89.—This plate illustrates the rare splitting off of part of the outer table of the head of the tibia, including the upper tibio-fibula articulation. The injury was sustained in hunting. The rider was thrown from his horse, while his leg was jammed tight between the horse and the side of a ditch. (Rebman, Ltd.)

The author desires to call attention to the special lesson to be obtained from the series of radiographs that follow. They are reproduced here, not as fine examples (though they were extremely fine in the originals), but to teach the reader that the ordinary radiographic prints of medical journal articles on X-ray work are nearly worthless as diagnostic illustrations. Compare these with your own finest negatives and see how the quality of diagnostic value has been lost in the presswork. Study these as warnings against judging radiography by presswork copies instead of fine originals, and realize the great difference between electrotype and negatives.

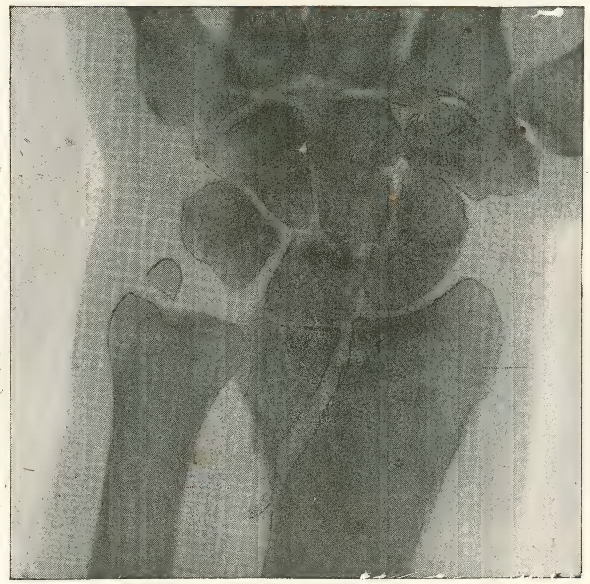


PLATE 90.—Fracture of radius and ulnar styloid. In examining these reproductions the reader will learn much from a careful study of such definition as is still poorly retained in the half-tone. The markings of the joints between the small bones tell the expert very nearly the position of the tube when the exposure was made and evidence is given of the shortness of the exposure-time. (Rebman, Ltd.)

PLATE 91.—Colles' fracture with backward displacement of the shaft of the radius. An antero-posterior view of the same case which is not here reproduced shows separation of the ulnar styloid apophysis.

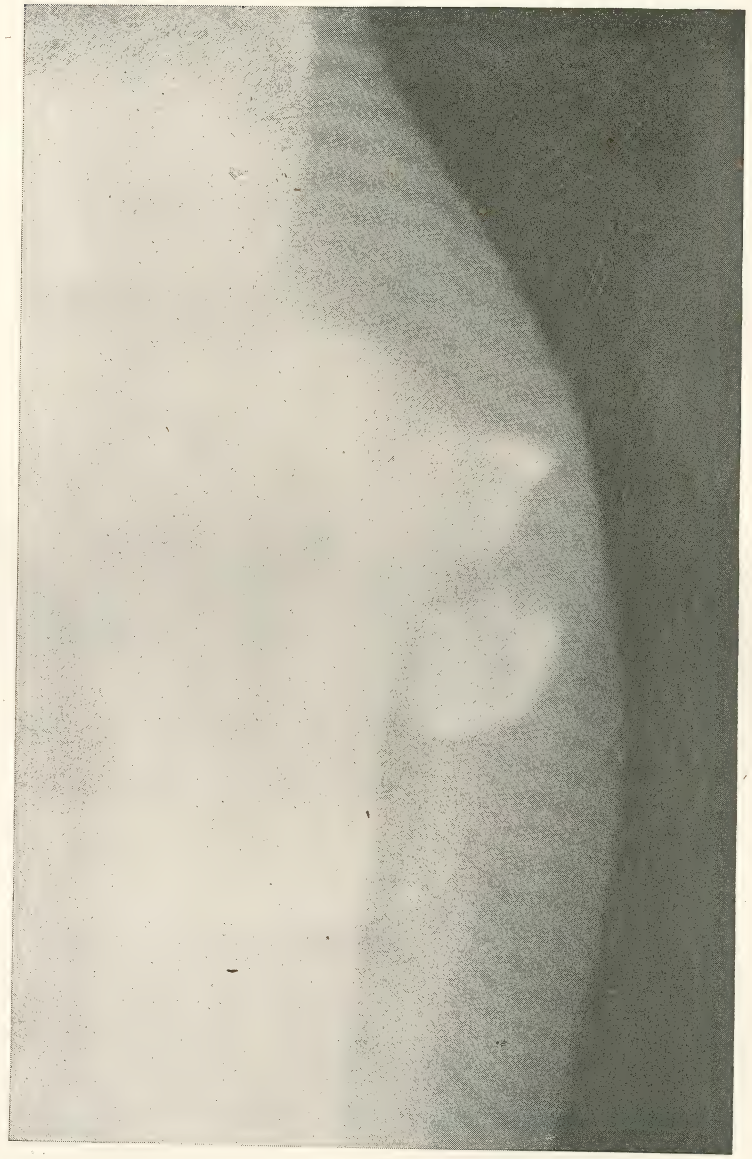


PLATE 92.—A Fractured Patella. Radiographed two days after the injury. (Rebman, Ltd.)

often furnishes precise evidence. Whether there is comminution, or impaction, or the intervention of muscular tissue, or intra-articular fracture, or fracture combined with dislocation, can at once be clearly determined.

"If the picture be fixed on a photographic plate the nature of the injury can be studied at leisure, and the proper line of treatment decided on without subjecting the patient to any tentative manipulations. After a dressing is applied the X-rays can verify the proper position of the fragments. In short, the proper execution of all therapeutic points can be verified throughout the course of the case, the dressing, even if a plaster splint, being no obstacle to the rays. If the therapy proves to be imperfect the rays show the nature of the condition. It is easily determined, for instance, whether an ankylosis be fibrous or osseous, and consequently the question of indications—whether the breaking up of adhesions or resection—can be settled at once. Even the shoemaker can profit by the X-rays, which will prove whether shoes fit accurately—an item of great importance in the after treatment of fractures of the bones of the feet and in club-foot."

"It is needless to call attention to the frequent importance of a skiagraphic proof in court for the protection of the surgeon as well as of the patient. The greatest benefit obtained from the rays in the proper judgment of the various types of fractures is in connection with those situated in the neighborhood of joints. The special uses of X-rays in diagnosticating the various types of fracture may be grouped as follows:

"Fractures of the *clavicle* are, in general, easily recognized without the rays. Still there are rare cases of infraction and fissure in which no deformity or crepitus is observable, and which could not be recognized except by the aid of the rays.

"In fractures of the *scapula* the conditions are often so obscure that without skiagraphy the true nature of the injury may be veiled; for instance, when dislocation of the humerus is combined with fracture of the acromion. In fractures of the *humerus* it is the shoulder-joint and elbow-joint that require the use of the rays most frequently. Especially in reference to the elbow-joint it may be safely asserted that an exact diagnosis without skiagraphy is simply impossible in by far the great majority of cases. Skiagraphy will infallibly demonstrate the various types of elbow fractures; it will furthermore show whether the line of fracture is transverse or T-shaped, and whether there are any complications, such, for instance, as a fracture of the olecranon combined with dislocation of the radius.

"In fractures of the *forearm* it is the elbow-joint and the wrist-joint that especially require the use of these rays. In these cases, as well as in those previously noted, a large number of new facts have been revealed, which have entirely revolutionized our pathologic and therapeutic views.

"Fractures of the bones of the *hand* occur much more frequently than was formerly supposed. Fractures of the individual carpal and metacarpal bones, and even of the phalanges, were often mistaken for contusions.

"Fractures of the *pelvis,* the accurate recognition of which formerly offered the greatest difficulties, can also be readily demonstrated—the differentiation between contusion, fracture of the acetabulum or of the neck of the femur, and dislocation especially coming into question. Most valuable information can also be obtained as to the presence of impaction.

"In fracture of the *femur* it is not only the hip-joint that may require the use of the rays, but also the shaft and lower end of the bone. In the neighborhood of the knee-joint rapid swelling often absolutely prevents an accurate diagnosis except when the rays are employed. Furthermore, in all the different intra-articular complications the occurrence of epiphysial separation, and the question as to the transverse or oblique or T-shaped line of fracture can easily be settled.

"Fracture of the *patella* can easily be recognized without the aid of the rays. Still, there are some important questions—for instance, whether there are several fracture lines or whether the fracture is complete or incomplete—that could not be determined without the aid of X-rays. *It goes without saying that in the proper determination of the after treatment, in the correct restoration of the fragments, and in the confirmation of the result in the event of wiring, skiagraphic control is simply indispensable.*

"In fracture of the *leg* the difficulties were often insuperable before the discovery of X-rays. It is especially in the malleolar type that serious disturbances are observed. Particularly in regard to *Pott's fracture* many fresh facts were revealed by the rays, so that, just as in fracture of the lower end of the radius, our views have been changed completely. The number of fractures of the *ankle* formerly treated as sprains and dislocations, to the great disadvantage of the patient as well as of the surgeon, is legion.

"Fracture of the *foot* is also found to be more frequent than was formerly supposed. Individual fractures of the tarsal and metatarsal bones and of the phalanges were often erroneously taken for contusions. It has been found that the so-called œdema of the foot, so frequently found among the German infantry, is always due to a badly united fracture of a metatarsal bone.

"In fracture of the *ribs* and of the *sternum* skiagraphy will often prove to be useful from the stand-point of jurisprudence.

"In fracture of the *vertebræ* the exact location of the fragments is of great importance in determining the advisability of operating.

"In fractures of the *skull,* those of the face and of the inferior maxilla have derived the most benefit from X-rays. Fractures of the base are still with difficulty demonstrated. In fracture of the larynx the question of differentiation is easily settled by the rays." (Beck.)

The value of X-rays in the examination of fractures would appear so obvious to lay readers and mere medical practitioners as to

PLATE 93.—Showing a case of rare dislocation of the metatarsus. Taken at the Sydney Hospital, New South Wales. (Rebman, Ltd.)

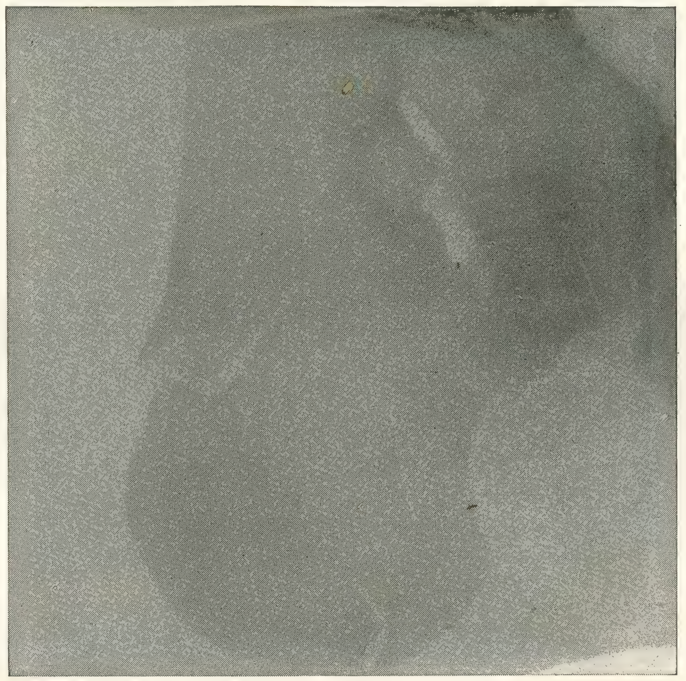


Plate 94.—This plate illustrates a fracture of the calcaneum caused by a fall of twelve feet. The man fell through a scaffolding and struck on his feet. (Rebman, Ltd.)

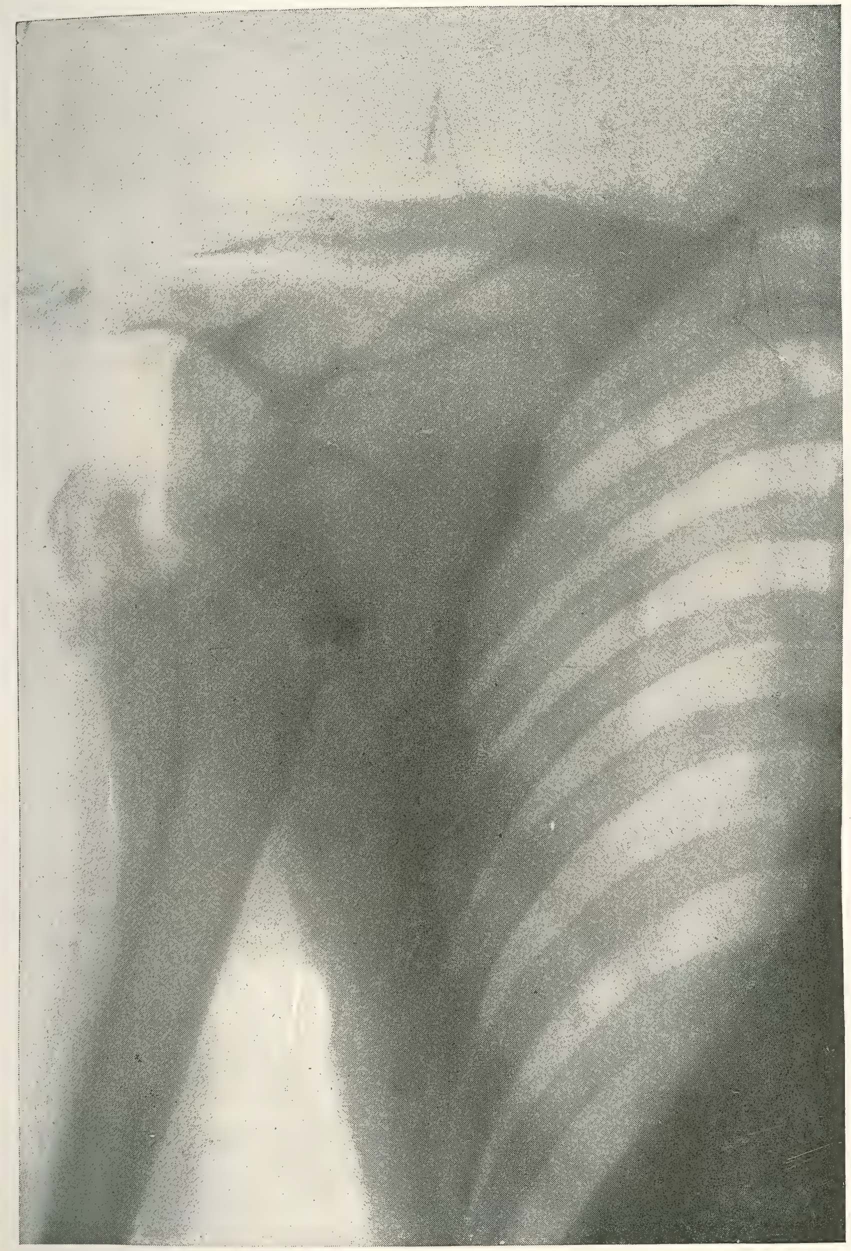


Plate 95.—An unreduced dislocation of the shoulder with fracture of the humerus. This picture was taken after patient was seen by a local surgeon, diagnosis of dislocation made, and reduction asserted. (Rebman, Ltd.)

PLATE 96.—Fracture of radius and ulna with dislocation of radius backward. (Rebman, Ltd.)

admit of no controversy, and even the majority of ordinary surgeons welcome their aid and are grateful for their assistance. In peaceful hospital and private practice there are many occasions when an X-ray examination will please the patient better than the pain of manipulations and searchings for crepitus and false motion. In military surgery a writer has said that the X-ray and the Red Cross nurse are the two lone stars in the dark horizon of a wounded soldier.

More than a year ago Professor Von Bergmann of Berlin declared that knowledge of fractures during the last ten years had made *two* important advances. *One* of these was the recognition of the seat of fracture and of the pathological anatomy of the osseous region *by means of the fluoroscope and the radiograph.* The other advance relates to treatment. When the stereoscopic fluoroscope is perfected it will open a new era in the surgical examination of fractures, but the services already rendered by X-rays are too great to be obscured. While the X-rays may be said to be useful in *all* fractures, yet among those in which it is *most* valuable the following are mentioned by Manoury:

"1. Fractures of the upper extremity of the humerus, which so often produce stiffness and ankylosis attributed to peri-arthritis.

"2. Fractures of the lower end of the radius, which frequently accompany lesions of the carpus.

"3. Fractures of the leg, especially those involving the articulation of the tibia and tarsus, in which last radiography is the only means of obtaining exact information as to the relations of the astragalus, tibia, and fibula, a matter of great importance in the prognosis and treatment of these fractures.

"4. Fractures of the astragalus, which some years ago were erroneously considered to be very rare.

"5. Fractures of the metatarsal bone, the anatomical condition well-known to military surgeons, but the cause of which was discussed without being suspected until the advent of X-rays. Radiography is also as useful in the *treatment* of fractures as in their diagnosis, *facilitating reduction*, and enabling the position of the ends to be inspected, and, if necessary, corrected, before consolidation. It also shows in what fractures wiring may be indicated, examples of which are to be found in the elbow and ankle."

Leonard, in speaking of the advantages gained through the use of the X-ray, particularly alludes to the avoidance of much interference with dressings in cases of fractures, and the obtaining of definite and absolute knowledge in fracture examination, without pain or discomfort to the patient. By the X-ray many forms of apparatus to produce immobility have been shown useless. Great variations have been shown to exist from the representations in text-books, enforcing attention to the necessity for careful study of the mechanical elements involved in each fracture. Omitting copies of the pictures, a few reported examples will show the concrete value of X-rays in individual cases.

"Case 1 illustrates the value of X-ray information. A sailor nineteen years of age was injured one week prior to admission to the hospital, by falling from the yard-arm. When admitted, it was found that he had a fracture of the right femur. The part was radiographed to find the exact condition of the fragments. The result showed that the loose fragment of bone had become displaced in a transverse position to the shaft, and in addition to this it was found to be cracked lengthwise. Imagine making this diagnosis without the aid of X-rays.

"Case 2 is the knee of a man who fell from a moving car. He landed on his feet, but on attempting to walk was unable to place any weight on his left leg. A radiograph showed a longitudinal fracture of the head of the tibia. A somewhat similar case involving the opposite side of the head of the tibia, is shown by a radiograph of the right knee of a man who was thrown from a bicycle and sustained a fracture of the inner portion of the head of the fibula.

"Among the more common injuries what is called a 'severe sprain' is one of the most unsatisfactory as far as treatment and diagnosis are concerned. If there is no easily distinguished fracture and no extensive laceration of the muscular and fibrous tissue, the case is usually considered simple. There are, however, many that give unsatisfactory results, have a very prolonged convalescence, and a persistent and sometimes extensive interference with full use of the joints. These latter cases are sometimes classed as cases of chronic rheumatism when seen long after the sprain. A careful study of a number of so-called 'severe sprains' of the wrist that have come under our observation during the past two years, have led us to conclude that many of them are really more or less extensive fractures of one or more of the carpal bones. The case of a young man who fell from a bicycle several days before applying at the hospital, illustrates this. He had hit an obstruction, been thrown from his wheel, struck on the palm of his hand, remounted his wheel and rode home, a distance of fourteen miles, practically without pain. The next day the wrist was getting steadily worse, and he painted it with iodine. This did not relieve the pain, and the following day he consulted a surgeon. When examined at the hospital, he presented a wrist that was decidedly swollen and painful. A careful clinical examination did not reveal any evidence of a fracture. On account of the nature of the accident, the pain and the swelling, it was thought advisable to make a skiagraph, which showed a transverse fracture of the scaphoid, with slight impaction.

"The reason, no doubt, that more of these fractures have not been recognized, even by the aid of the X-rays, is that many of them are

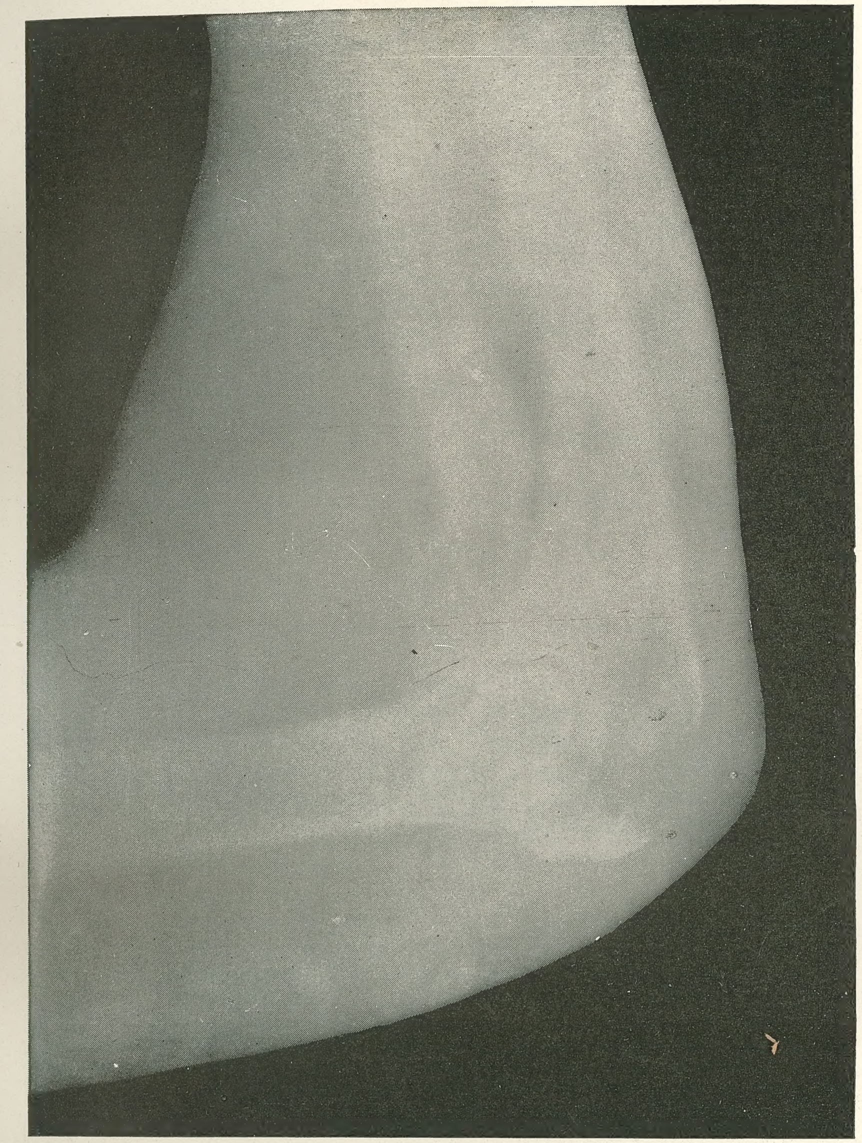


PLATE 97.—A fractured olecranon before treatment. A woman aged 61 fell down several stairs, striking on her elbows. The joint was movable, but flexed, and was so swollen that accurate diagnosis by manipulation was impossible. The radiograph showed the fracture, with about an inch (in the life-size picture) between the fragments. The next plate shows the same repaired with screw. (Rebman, Ltd.)

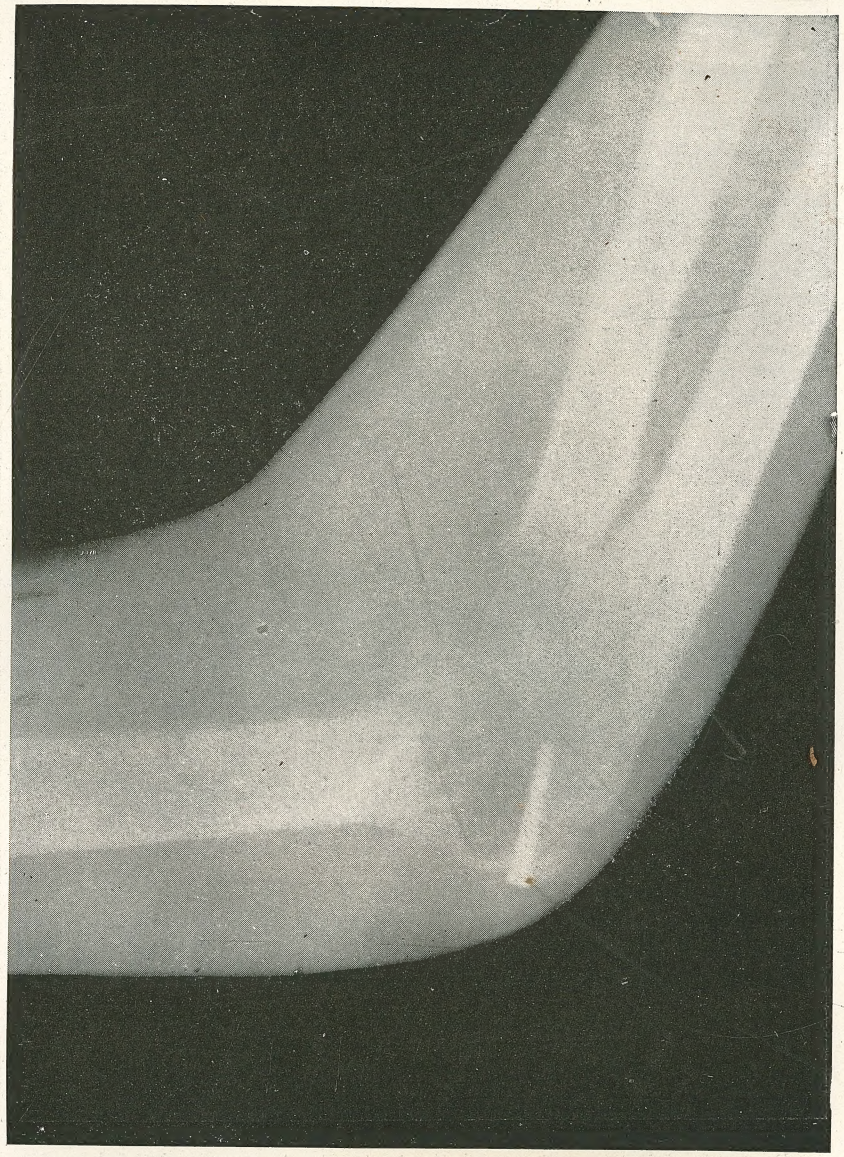


Plate 98.—Fractured olecranon after treatment. Ten days after the injury shown in last plate the fragments were brought together and held in place by the screw which shows in this plate. The patient left the hospital in eight weeks and works at the wash tub with the screw in situ. (Rebman, Ltd.)

Plate 99.—Fracture of olecranon, treated in next plate. (Rebman, Ltd.)

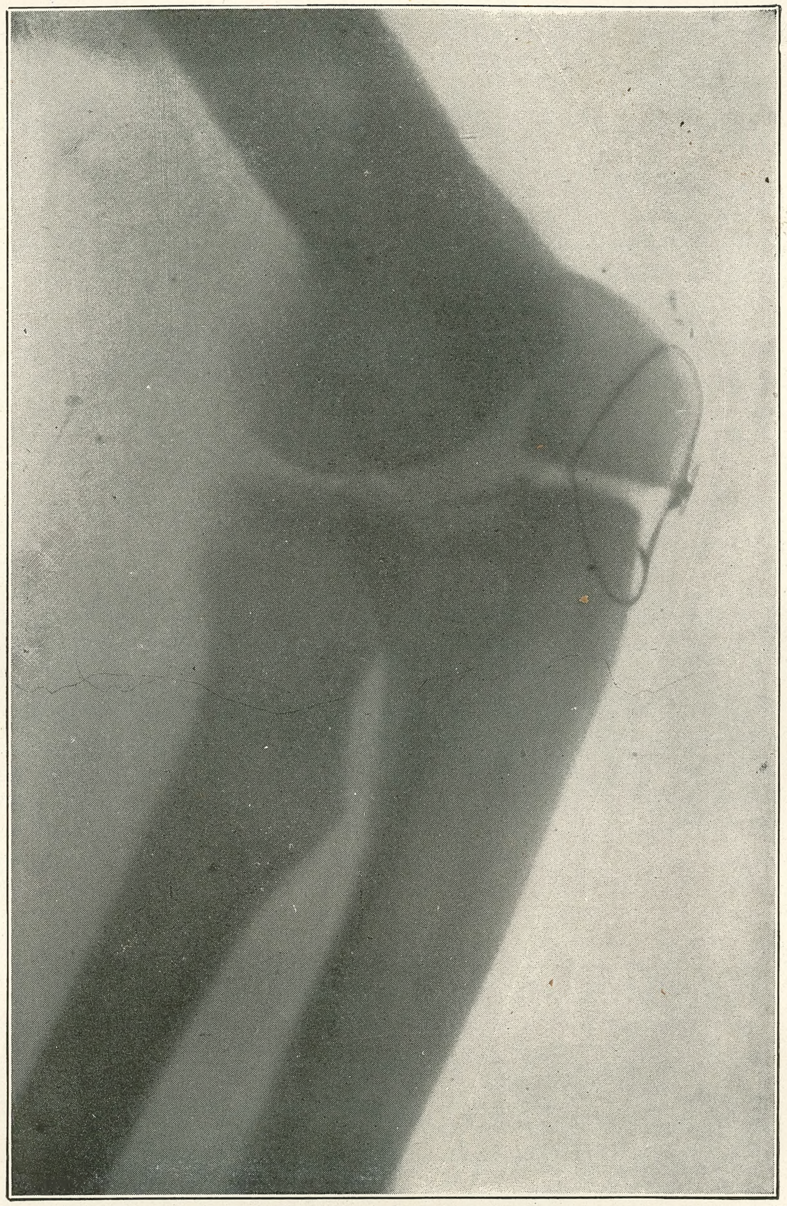


PLATE 100.—This picture shows a fracture of the olecranon treated by wiring. If the reader compares it with the preceding fracture the closer apposition of the fragments appears to be obtained with the screw, but the light space in the wired bone may possibly be filled in by nature with a cartilaginous matrix which will in time become bone. The second of these pictures was taken two months after the operation.

obscure, the lesion not being extensive, and there being little or no displacement. The lines of fracture are more or less hidden, and are seldom easily recognized in the somewhat complicated shadows cast by the normal carpal bones. Even normal wrists may show a slight difference in the development of the various bones, or in their densities. We have seen several cases in which, even after a number of years, no bony union had taken place between the fragments. A case of this kind is apt to be mistaken for a recent fracture unless we take into account the history and clinical symptoms. We have seen in less than three years fifty-two cases in which one or more of the carpal bones had undoubtedly been injured at some time, and in which the patients were at the time suffering pain or were being inconvenienced by the injury or its effects."

"A case of 'sprained fracture' was a man sixty-six years of age, who had been run into and knocked down. The wrist pained, especially on motion, but was only slightly swollen. The radiograph of the left wrist showed the separation of a small fragment of bone from the outer edge of the scaphoid. For comparison the picture of his right wrist was taken, which seemed to show a fracture of the styloid process of the ulna. Upon inquiry it was found that he had sprained his right wrist thirty years before, and the joint was a long time regaining its usefulness."

"The radiograph of another case supposed to have simply sprained his wrist, shows an impacted fracture of the scaphoid. Another case in which the physical examination was misleading, showed a callus on the ulna resulting from a fracture seventeen years before. In another case, presenting an acute arthritis with the wrist much swollen, inflamed, and practically ankylosed, the radiograph showed an old injury to the scaphoid. The patient had 'sprained' his right wrist some time previous, and it had been giving him more or less trouble ever since. The recent arthritis had resulted from the persistent irritation of attempts at use." (WILBERT.)

A Differential Diagnosis.—Owing to the mixed relations of supposed sprains of the wrist, fractures of the carpus, rheumatism, and arthritis, which the X-ray has shown to exist, a study of the differential diagnosis is important. Clinically, the features of a fracture of the carpus may not be definite or well-defined. The history of a fall or injury may be insignificant. It has been repeatedly shown that fracture has resulted from very slight violence. Pain is not diagnostic. The swelling serves often to obscure the diagnosis without presenting any characteristic features. Crepitus is rarely obtained, and deformity may be nearly absent under the mask of the swelling. A fracture of the scaphoid is the most common of the simple fractures of the carpus. It may vary from the tearing away of a slight splinter of bone by the attached ligament to a complete transverse or impacted fracture. Either in combination or alone, the scaphoid, the os magnum, the semilunar, and the cuneiform bones of the carpus have been found injured in cases supposed clinically to be only severe sprains. When fracture of one or more carpal bones accompanies a fracture of any of the related long bones of the hand or wrist, it may be overlooked even in the X-ray examination, unless the entire part is subjected to scrutiny.

But in the case of a simple sprain an adequate X-ray examination comparing both hands under the axis of the rays will show normal bone. If inflammation is present the diagnosis of the nature of the arthritis may be assisted by X-rays. If an ununited fracture or necrosis existed it would show on the negative with a normal condition of the remaining bones and cartilages. A previous history leading to the diagnosis of rheumatoid arthritis would be reinforced if the negative showed ulceration or destruction of the cartilages. The radiograph will be distinguished between an old fracture in the body of a bone and a necrotic process following the destruction of the cartilage surrounding the bone. The more or less clean breaks of the bone with inflammatory exudate surrounding it would indicate a fracture, while a negative showing a more or less irregular breaking down of several carpal bones would point to an advanced case of rheumatoid arthritis. If the radiograph shows a more or less diffusion of inflammatory exudate throughout the carpus when an arthritis is discovered after the prolonged immobilization of the wrist-joint for injury about the lower end of the forearm, it would indicate a not infrequent type of arthritis, which may develop in cases tied up too long with the idea of getting a better union of the fragments. If the examination is not made till long afterward, however, the necrotic appearance on the negative will resemble somewhat a radiograph of an advanced case of rheumatoid arthritis, but the history and the condition of other bones will interpret the diagnosis. It may not be out of place here to say that, both in recent and older cases of any of these conditions, the best therapeutic results may be obtained by certain applications of electricity and motor-massage, full directions for which are given by the author elsewhere.

CHAPTER XXX

X-RAYS IN MILITARY SURGERY

Studies and Conclusions of Experience.

Certain lessons derived from X-ray experience in military surgery contain instruction for the general surgeon who deals with similar injuries in times of peace. The major *lessons* that appear from the Surgeon General's report of X-ray work in our war with Spain will here be grouped for the reader in concise form. Official documents are closely followed.

"During 1898 the United States Army had twelve X-ray coils and five Static machines. When working properly both apparatus produce X-rays of practically equal power and efficiency, but are so utterly unlike in construction and require such different means for their manipulation that they are not under all conditions equally adapted to the requirements of military surgery.

"The use of the X-ray has marked a distinct advance in military surgery. It has favored conservatism and promoted the aseptic healing of bullet-wounds made by lodged missiles in that it has done away with the necessity of exploration by probes and obviated the dangers of infection and additional traumatism in this class of injuries. In gunshot fractures it has been of great scientific value in showing the character of the bone lesions, the form of fracture, and the amount of bone comminution produced by the small-calibre and other bullets—*information which could not otherwise be obtained in the living body.*

"In the treatment of these traumatisms the X-ray has been of great value in determining the course to be pursued, as its use, together with the course of cases under treatment, has shown that the *aseptic* or *septic* condition of the wound is of far greater importance than the amount of bone comminution. This is illustrated by cases of extensive comminution with aseptic wounds which progressed favorably with a minimum of immediate and remote ill-effects; while cases of slight bone traumatism with infected wounds were much more difficult to treat and more serious in results.

"Of the total number of wounded coming under treatment on the American side during the Spanish War the mortality was only 6.64 per cent. In ten other tabulated wars it ranged from ten to fifteen per cent. An effort was made to determine how much of this