A MANUAL

OF

X-RAY TECHNIC

BY

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WITH 42 ILLUSTRATIONS

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PREFACE

This short manual on the technic of X-ray examination has been prepared with a view to the needs of the medical service of the United States Army. The small number of medical officers in the service necessitates frequent change of station, so that it often becomes necessary for one to familiarize himself in a comparatively short time with the essentials of radiologic technic. With this in mind it has been the author's aim to limit this work to the absolute essentials, a knowledge of which will enable the operator to do satisfactory work in X-ray diagnosis.

The book may also be found useful by that increasingly large number of physicians and surgeons in private practice who find it necessary or expedient to do their own X-ray work for diagnosis. Resort to a specialist in radiology is earnestly recommended whenever such services can be obtained, but in the smaller cities and towns this is often impossible. It is believed that mastery of the facts contained in this manual will enable those so situated to do satisfactory radiography.

In the preparation of this book many of the larger text-books and many monographs have been freely drawn upon. It has not been deemed necessary, however, to give an extensive bibliography, for the publications in the entire field of radiology, from the time of the discovery of the X-ray up to the present, are covered in that excellent work, "Die Röntgen-Literatur," by Prof. Dr. Hermann Gocht.

Only a few reproductions of radiograms are published as illustrations to the text because it is believed that ability to interpret radiograms can be gained only by experience with the originals.

Every X-ray operator is urged to make himself thoroughly familiar with the details of construction of the particular apparatus with which he is working. He is then in position to keep it constantly at its point of maximum efficiency. With his apparatus in good condition he can then gradually master the small details so essential to good X-ray work, and with practice in examining radiograms he will finally acquire ability to properly interpret them and so to arrive at correct diagnoses.

A. C. Christie.

Washington, D. C., October, 1913.

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CHAPTER I.

Electricity and Magnetism.

Nature and Properties.—The nature of electricity is known only by its effects. The word is derived from the Greek elektron, meaning amber, in which substance Thales, about 600 B.C. first noticed some of the phenomena of electricity. The word "electrics" was first applied by Dr. Gilbert about the year 1600 A.D. to certain substances like amber, sealing wax, etc., which become electrified by friction. The phenomena of electricity are supposed to be due to some stress or strain in the ether.

Electricity may be either static or dynamic.

Static electricity is electricity at rest; it is produced by some form of friction or "influence" machine.

Dynamic electricity may be galvanic or faradic.

Faradic electricity is a derived (induced) form of electricity, so named from Michael Faraday, in which there are rapid alternations of direction.

Galvanic electricity is that produced by the galvanic cell, which, in its simplest form, consists of a jar of dilute sulphuric acid in which are dipped a plate of zinc and one of copper (Fig. 1).

According to the theory of Arrhenius the affinity of the zinc for the acid radical SO_4 starts a chemical

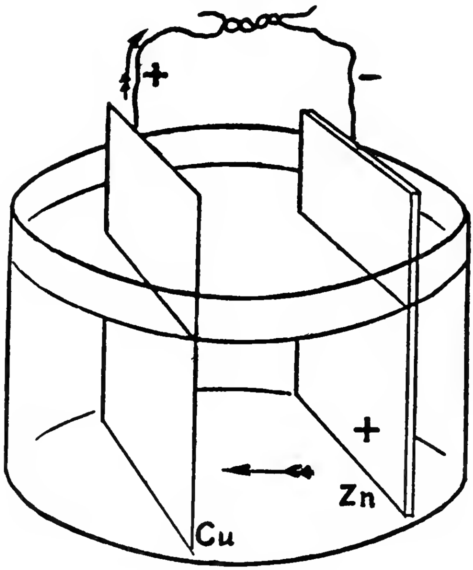


Fig. 1.—The galvanic cell.

reaction which results in the determination of positive ions toward the copper and of negative ions toward the zinc. In consequence of this ionic movement an electrical current is produced from the zinc to the copper through the liquid, and outside of the cell from the copper to the zinc through a connecting wire.

Polarization of a galvanic cell takes place by the collection of bubbles of hydrogen gas on the copper plate and interferes with or stops the action of the cell. Various devices have been used to prevent this.

Types of Cells.—There are many different types of cells, but only two will be described here.

The Daniell cell consists of a zinc plate immersed in dilute sulphuric acid contained in a porous vessel, outside of which is a perforated copper plate surrounded by a solution of copper sulphate. The hydrogen is taken up by the sulphate before it reaches the copper plate. This cell is very constant because polarization is entirely prevented.

The potassium bichromate cell consists of zinc and carbon plates immersed in a solution of potassium bichromate in dilute sulphuric acid. The action of the sulphuric acid on the bichromate liberates chromic acid, which oxidizes the hydrogen to form water and thus prevents polarization.

Definitions of Electrical Terms.—The *ohm* is the unit of electrical resistance and is represented by the resistance of a column of mercury 106.3 cm. long and 14.4521 gm. in mass at 0°C.

The *ampere* is the unit of current strength and is that current which deposits silver at the rate of 0.001118 gm. per second.

The *volt* is the unit of electrical pressure or electro-motive force; it is that electro-motive force which applied to one ohm produces one ampere.

The *coulomb* is the unit of quantity, being the quantity of electricity conveyed by one ampere in one second.

The *watt* is the unit of power. One ampere with a pressure of one volt produces one watt.

These terms are analogous to certain hydraulic terms. The voltage or electro-motive force corresponds to the head or pressure of water. Electrical resistance, the unit of which is the ohm, is analogous to the frictional resistance to the flow of water in a pipe. The current strength, whose unit is the ampere, is represented by the rate of flow of the water through the pipe. The quantity of electricity per second (coulomb) corresponds to the amount of water delivered per second. In other words, if an electro-motive force of one volt is working against a resistance of one ohm it produces a current of one ampere, which, flowing for one second, produces a coulomb of electricity.

OHM'S LAW.—Current strength in amperes is equal to the electro-motive force in volts divided by the resistance of ohms.

$$C=\frac{E}{R} \text{ or } E=C\times R \text{ or } R=\frac{E}{C}$$

METHODS OF GROUPING GALVANIC CELLS.—Cells may be grouped in series or in parallel. They are grouped in series (Fig. 2) when the positive pole of one is connected to the negative of the next, and so on. The grouping is in parallel or multiple arc (Fig. 3)

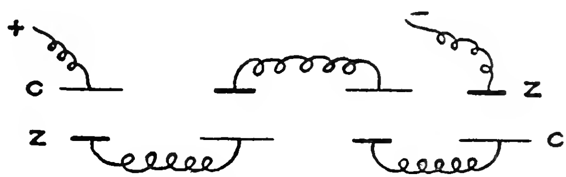


FIG. 2.—Cells grouped in series.

when all of the positive poles are connected together on one side and all of the negatives on the other.

By connecting cells in series a relatively high voltage may be obtained. The E. M. F. is made to

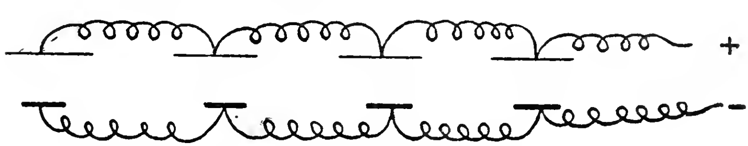


FIG. 3.—Cells grouped in parallel.

equal the E. M. F. of each cell multiplied by the number of cells. With n cells grouped in this manner we have the following adaptation of Ohm's law:

$$C = \frac{nE}{nr + R},$$

R being the external and r the internal resistance. From this it is evident that when the external resistance is great, grouping cells in series will give a greater current than parallel grouping.

By connecting cells in parallel the E. M. F. remains that of only one cell, while the resistance becomes that of one cell divided by the number of cells. The amperage is thus increased and becomes the amperage of one cell multiplied by the number of cells. The formula for Ohm's law now becomes

$$C = \frac{E}{\frac{r}{n} + R}.$$

This method of grouping would therefore give the best results when the external resistance is small.

Kinds of Electrification.—Electrification may be manifested by repulsion as well as by attraction, and is of two kinds, opposite in character. The electrification developed by rubbing glass with silk is called positive, and that developed by rubbing sealing wax with flannel is called negative. Bodies similarly electrified repel each other and those oppositely electrified attract each other.

Conduction.—Electrification by conduction is the process of charging a body by putting it in contact with an electrified body. The charge thus produced is of the same kind as that of the communicating body.

Induction.—This is the process of electrifying a body by bringing it near to, but not in contact with, an electrified body. The charge thus produced is of the opposite kind to that of the communicating body. A current of electricity in one of two wires placed near each other produces no effect in the second wire so long as the current flows steadily, but whenever the current is increased or decreased in strength a current is " induced " in the second wire. This current in the second wire depends upon the presence of a " field of force " which surrounds every electrically charged body. At the instant when the primary current begins or increases in strength a weak current in the opposite direction is generated in the secondary wire; at the instant when the primary current stops or decreases in strength a strong current in the same direction is generated in the secondary.

MAGNETISM.—Magnetism is the property by virtue of which a body attracts iron or steel, and which causes the iron or steel when suspended to take a position pointing approximately north and south.

A magnet may be a natural one, as lodestone, or an artificial one. Artificial magnets are either permanent or temporary.

The ends of a magnet are called the poles. The end which points to the north when the magnet is freely suspended is the north, marked, or + pole, while that which points to the south is the south, unmarked, or – pole.

MAGNETIC FIELD.—When a bar magnet is placed beneath a sheet of paper on which are some iron filings, the filings will arrange themselves in lines radiating from each pole of the magnet as shown in Fig. 4. The area surrounding any magnetic body is called a magnetic field; it is the space through which the magnetic force acts. The lines of force are supposed to flow from the north to the south pole outside of the magnet and in the opposite direction inside, making a complete circuit.

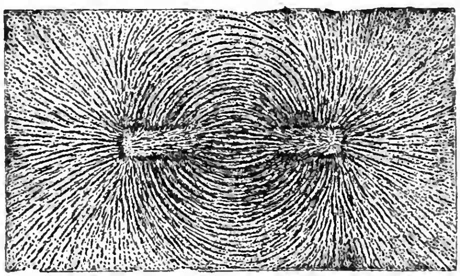


Fig. 4.—Action of bar magnet on iron filings.

Electro-magnetism.—It can be shown experimentally that an electric current has magnetic properties; it will deflect the magnetic needle and will cause iron filings to arrange themselves as they do when placed in the field of a magnet.

A coil of wire through which a current is passing is called a solenoid and has all the properties of a magnet (Fig. 5). An electro-magnet is a bar of iron magnetized by an electric current passing through a coil of wire surrounding it (Fig. 6).

The strength of an electro-magnet is directly proportional to the strength of the current passing through the wire surrounding it, and to the number of turns of the wire. Since electric currents may be made very strong and since we may use as many turns of wire as desired, it becomes possible to make electro-magnets of enormous strength.

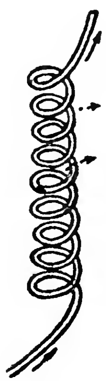


Fig. 5.—Solenoid.

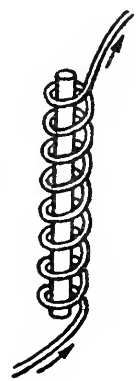


Fig. 6.—Electro-magnet.

Just as a current may be induced in one of two wires lying near each other by increasing or decreasing the strength of the current in the other wire, in the same manner a current may be induced in a coil of wire surrounding an electro-magnet but insulated from it. Upon this fact depends the action of induction coils, transformers, and motor generators, all of which are used in X-ray work.

CHAPTER II.

THE X-RAY. HISTORY AND PROPERTIES.

HISTORY.—The first vacuum tubes were made by Geissler about the year 1858. The passage of an electric current through these tubes, which were of low vacuum, caused a faint glow, varying in intensity with the degree of vacuum. Hittorf discovered about 1860 that the stream of discharge in a Geissler tube could be deflected by a magnet. It was in 1879 that Sir William Crookes, experimenting with tubes of very high vacuum, discovered the cathode rays. The glow which is present in the tubes of low vacuum has disappeared in these high vacuum tubes and is replaced by a greenish fluorescence of the walls of the tube. To this form of radiant energy Crookes gave the name of cathode rays.

The study of the discharge in high vacuum tubes was continued by many investigators, prominent among whom were Professor Hertz and his assistant Professor Lenard. In 1894 Lenard proved that the cathode rays caused phenomena outside of the tube, for experimenting with a tube having a sheet of aluminum in the end opposite to the cathode he observed that the radiation which passed through the aluminum could cause fluorescence in such substances as platino-barium cyanide. The next year, 1895, Prof. William Conrad Röntgen, at Würzburg, was experimenting with a high vacuum tube covered with black paper impervious to ordinary light. He noticed that a near-by paper covered with platinobarium cyanide fluoresced brilliantly while the tube was in action. Röntgen realized that this phenomenon must be caused by some hitherto unrecognized force, differing essentially from the cathode rays. Continuing his experiments Röntgen found that he could obtain shadow pictures on photographic plates of metallic objects in a box which was impervious to light, and also of the bones of the hand. He soon made his discovery public and it was only a short time until the use of the rays became general for diagnosis, and not long until valuable therapeutic effects were also observed.

THE CATHODE RAYS.—These rays are formed at the cathode of high vacuum tubes and are believed to be streams of electrified molecules shot off from the cathode. They have the following properties: (1) they can be deflected by a magnet; (2) they cause fluorescence and phosphorescence of certain substances; (3) they affect photographic plates like ordinary light; (4) they have no known effect on the bodily tissues.

The Relation of the Cathode Rays to X-rays.—The X-ray is formed at the point of impact of the cathode ray upon any solid object.

X-rays themselves are believed to be due to some disturbance in the ether and to be true rays. They have the following properties: (1) they are not deflected by a magnet; (2) they are invisible but cause fluorescence and phosphorescence of certain substances; (3) they affect photographic plates like ordinary light; (4) they travel in straight lines,—cannot be reflected or refracted; (5) they will pass through all known substances with varying degrees of intensity; (6) they cause the air to become a conductor and consequently cause the discharge of electrically charged bodies; (7) they have marked effects on the bodily tissues.

CHAPTER III.

APPARATUS FOR THE PRODUCTION OF X-RAYS.

THE apparatus necessary for the production of X-rays consists of suitable vacuum tubes, and of some form of installation for the production of suitable currents (static machine, induction coil, or transformer).

VACUUM TUBES.

The earliest forms of vacuum tubes were the Geissler tubes. These are of low vacuum and transmit electric currents more readily than air. During such passage the tube lights up with a soft luminous glow. As the tube is still further exhausted the current passes with greater difficulty and the luminous glow is replaced by a greenish fluorescence of the walls of the tube. When it reaches this degree of vacuum it is known as a Crookes tube and in it are produced the cathode rays. These in turn give rise to the X-ray wherever they strike any solid object.

The first X-ray tubes were somewhat conical in shape, the cathode, which was a flat disc, being placed in the small end (Fig. 7). The cathode rays were thus thrown upon the opposite end of the tube, the anode being ring-shaped so as not to obstruct the passage of the rays.

A great advance was made when Herbert Jackson devised a tube with a metallic target fixed within it at or near the focus point of the cathode stream (Fig. 8). This "focus" tube has undergone many modifications, among which the most important were the addition of an accessory anode, and of a device to regulate the vacuum.

A late model X-ray tube is one in which the air

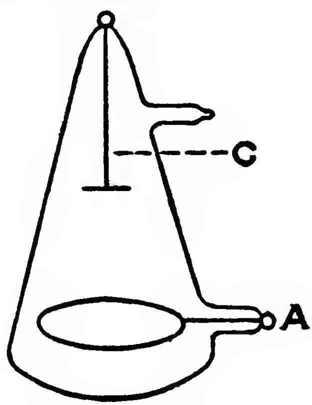


FIG. 7.—Early type of X-ray tube.

has been exhausted by means of mercury pumps to about one-millionth of an atmosphere. The essential parts of the tube are the cathode, the anti-cathode or target, the accessory anode, and some device to regulate the vacuum (Fig. 9).

The cathode of a focus tube is made of aluminum, because this metal does not suffer disintegration with consequent discoloration of the walls of the tube. The concave form of the cathode causes the cathode rays to be focussed upon a point on the target, or anti-cathode, as it is called.

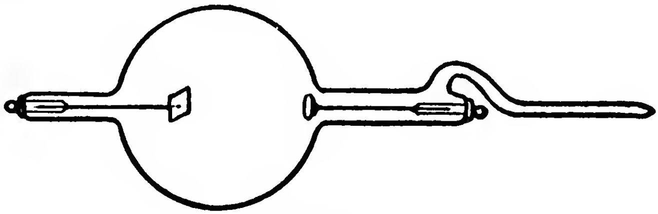


FIG. 8.—Jackson's focus tube.

As tubes are now constructed, the target is always an anode of the tube, but it is not necessarily so. The target is usually made of platinum, because the intense

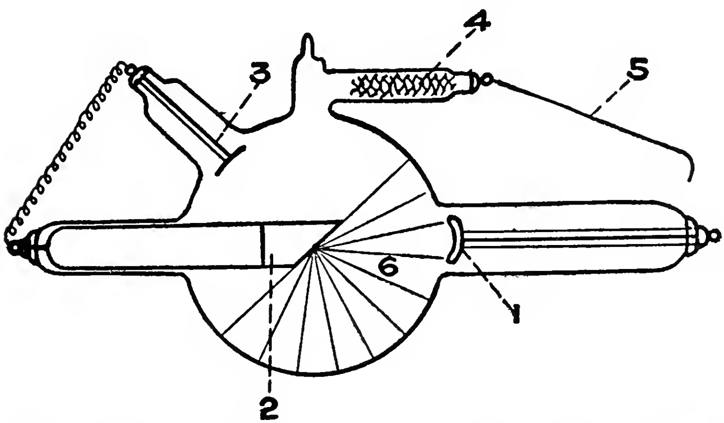


FIG. 9.—Modern type of X-ray or focus tube. 1, cathode; 2, target; 3, accessory anode; 4, vacuum regulator; 5, adjustable wire; 6, X-ray hemisphere.

heat generated at the point of impact of the cathode stream requires a metal whose fusing point is very high. Even platinum is not entirely infusible and often melts under the intense heat generated. Iridium and osmium have been used to some extent, and tubes are now being made with tungsten targets. The latter bids fair to entirely replace platinum for this purpose. The target is usually surrounded by a heavy block of some metal, such as copper, which is a good conductor of heat. As an additional precaution against fusing, the target is often placed at a point just beyond the mathematical focus of the tube. Water-cooled tubes, in which a column of water is sealed in a tube surrounding the anti-cathode, or allowed to flow through it, are also used to prevent fusing of the target. If certain defects, such as the danger of breakage, could be overcome in these tubes they would be ideal for X-ray work. The target is placed obliquely to the axis of all X-ray tubes so that the greater part of the X-rays are thrown out at one side.

The accessory anode is made of aluminum. It is connected to the anti-cathode by a wire outside of the tube. Tubes furnished with an accessory anode do not increase in resistance so rapidly as do those of older models.

Regulating the Vacuum in the Focus Tube.—The tendency of the X-ray tube to increase in resistance, making it increasingly difficult for the current to pass through it, has caused the introduction of many contrivances for lowering the vacuum when it has become too high. One of these was the osmo-regulator of Villard. It consisted of a platinum pin sealed into the tube with one end projecting outside. Heating the projecting end with a flame caused the platinum to become porous and to absorb hydrogen, thus lowering the vacuum of the tube.

Baking a tube in an oven at 200° to 300° F. for several hours will also lower the vacuum.

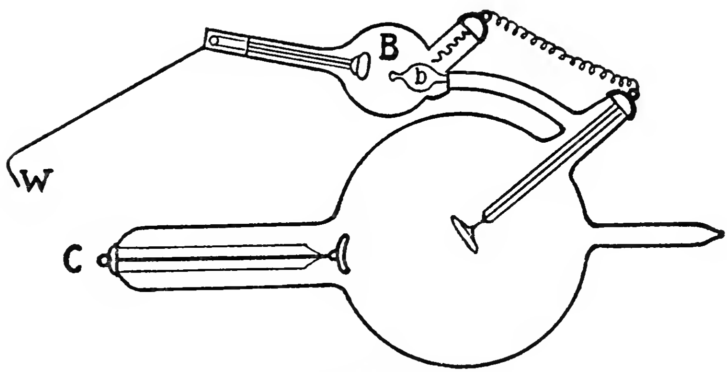


Fig. 10.—Queen's self-regulating tube.

In 1896 Queen's self-regulating tube came into use (Fig. 10). This tube had a relatively large accessory bulb *B* in which was sealed a smaller bulb *b*, the latter containing some chemical such as potassium chlorate. The smaller bulb connected directly with the main bulb. When the vacuum in the main bulb was too high the current could no longer pass directly through the tube but sparked across the path of less resistance from the cathode *C* to the end of the adjustable wire *W*, causing the potassium chlorate in the small bulb to become heated. The vapor given off into the tube from the potassium chlorate lowered the vacuum in the main bulb until the current could pass directly through, when the sparking from the cathode to the adjustable wire ceased.

The regulating device most largely used at present is one in which the accessory tube connects directly with the main bulb (Fig. 9). Asbestos is the substance usually used instead of the chemical of the old Queen tube. When the current sparks across from the cathode to the adjustable wire, air is forced out of the interstices of the asbestos and the vacuum consequently lowered. Instead of using the adjustable wire on the tube the regulating device may be connected by a third wire to an adjustable spark gap on the coil or transformer. This is the most convenient method since it enables the operator to regulate the vacuum from a distance.

When new tubes are ordered it is necessary to specify whether they are to be used with a coil or a transformer, since tubes pumped for use with a coil are of too high vacuum for use with a transformer.

When a new tube is received it is usually found to be of relatively low vacuum, but after being used a few times it reaches its point of maximum usefulness.

The vacuum then seems to remain about stationary for some time and then gradually increases until it reaches a point where it must be lowered every time it is used. Finally the vacuum becomes so high that it can no longer be lowered sufficiently to allow the current to pass.

Directions for Regulating the Vacuum.—If the current cannot pass through the tube on account of the high vacuum it sparks across between the positive and negative terminals of the coil or transformer. An adjustable spark gap is provided so that the operator may measure the length of the spark. The length of spark that a tube will " backup " is a measure of the resistance of that tube.

If the tube is too high to allow the current to pass when the latter is at its full strength, the end of the adjustable wire should be placed at a distance of about two inches from the cathode (never touching it) and the weakest current possible allowed to spark across to the regulator. The wire is then moved to a distance of five or six inches from the cathode and the current turned on to its full strength. This process is repeated until the tube lights up properly and there is no sparking at the parallel spark gap. The same method is followed when the adjustable regulating spark-gap on the apparatus is used instead of the adjustable wire on the tube. Great care must be exercised in this matter of lowering the vacuum of a tube for it is exceedingly easy to lower it to such an extent as to render it valueless until it is re-pumped. If a strong current is used for regulating it will cause a thick yellow spark to jump across and probably destroy the vacuum.

To increase the vacuum of a tube a weak current may be run through it in a reverse direction for several times. If this is done every day for considerable time the tube becomes higher. A tube will also increase in resistance by constant use.

An X-ray tube is said to be soft when the vacuum is low and hard when it is high. The penetrative power of the rays increases with the degree of vacuum and with the strength of the current.

When working well the tube shows a well-marked hemisphere of greenish fluorescence in front of the target, while the part of the tube behind the target is dark.

Secondary Rays or Sagnac Rays.—These are rays given off when the X-ray strikes an object, as parts of the apparatus or tissues of the body. They pass in all directions and may blur the radiogram; they may even pass through the plate in the wrong direction.

Indirect Rays.—These are rays formed at the extremities of the arc and are useless for radiography.

The useful rays are those which come off at right angles from the target. The use of a diaphragm with a circular aperture eliminates most of the indirect rays, and also much of the secondary radiation.

Means of Determining the Intensity or Penetrative Power of the X-rays.—(1) *Appearance of the Tube:* In a tube of low vacuum the greenish fluorescence is soft and somewhat yellowish and the tube is not so distinctly divided into hemispheres. There is also a bluish color just in front of the cathode, and if the vacuum is very low a blue line may be seen extending from the cathode to the target. In the tube of high vacuum the fluorescence is of a bright green color and the tube is divided into two distinct hemispheres. (2) *Fluoroscopy:* Using the fluoroscope and some object such as a skeleton hand as an indicator. It is very dangerous for the operator to use his own hand because of the liability to X-ray dermatitis and its sequels. (3) *The Spark Gap:* The length of the spark that a tube "backs up" varies with the strength of the current as well as with the resistance of the tube, but if taken in conjunction with the reading of the milliamperemeter it is a good indication of the penetrative power. (4) *The milliammeter:* The reading of the milliammeter also varies with the strength of current and resistance of tube. It must be remembered that a high reading does not necessarily mean a tube of high penetration. Indeed it more often means just the opposite. The lower the tube the greater the amount of current that can pass through and consequently the higher the reading of the milliammeter. But if the tube gives a spark of four and a half to six inches in length, and at the same time the milliammeter has a high reading, then the degree of penetration is great. (5) *The radiochromometer of Benoist:* The construction of this instrument is based upon the fact that different metals vary in their penetrability to the X-ray. A silver disk 0.11 mm. in thickness placed in the centre of the device is used as the standard of comparison. Round this centre are placed layers of aluminum of varying thickness. The diaphragm is rotated until the tint of the sector corresponds to that of the centre, when it is read off, as No. 1, 2, 3, 4, etc., Benoist.

For radiographic work the length of the spark gap and the reading of the milliammeter taken together probably afford the most practical and best method of determining the degree of penetration.

Care of the X-ray Tube.—It is necessary to take certain precautions in using focus tubes in order to keep them at the point of maximum usefulness for the longest possible time. In cold weather the tube should be warmed before use. When hot it should not be allowed to cool off too suddenly. The lead wires ought not to come in contact with the tube when in action, since a spark may jump across to the glass and cause puncture. Keep tubes perfectly clean; a small particle of dust may attract the current and cause puncture. New tubes are likely to be rather unstable in vacuum and should be used cautiously with weak currents, and with very short exposures with strong currents, until they become seasoned. Avoid overheating the tube by too long or too frequent use. The place of greatest heating is around the cathode, and it is here that the greatest number of punctures occur.

Means of Determining the Positive and Negative Terminals.—In order to connect the X-ray tube properly it is necessary to know which is the positive and which the negative terminal of the apparatus from which the current is being taken. This may be determined in the following ways: (1) On the induction coil or transformer the left hand side is usually the positive pole; (2) if both poles are immersed in water, bubbles arise from the negative; (3) the negative pole ionizes a solution of potassium iodide, turning the solution red around this pole by liberating free iodine; (4) the spark at the negative pole is thick and white, while that at the positive is thin and wiry; (5) when the tube is properly connected, the anode to the positive terminal and the cathode to the negative, the tube lights up in the normal manner with well-marked hemispheres, while if the current is passing through in the opposite direction rings of light are seen extending around the tube in many different directions.

CHAPTER IV.

Apparatus for Exciting the X-ray Tube.

STATIC MACHINE AND INDUCTION COIL.

The apparatus used to excite X-ray tubes may be a static machine, an induction coil, or a high potential transformer.

The static machine is now little used for X-ray work, its use being confined to radiotherapy. It gives a very uniform discharge at exceedingly high voltage, but the amperage is so low as to necessitate unduly long exposures for radiographic work.

THE INDUCTION COIL.

An induction coil consists of a core of soft iron wire upon which is wound a primary coil of coarse wire. Upon the primary coil, carefully insulated from it, is wound the secondary coil. The latter is made up of very many turns of fine wire, while the primary consists of relatively few turns of coarse wire. A current is passed through the primary winding and magnetizes the iron core, thus setting up a strong magnetic field through and around the secondary winding. The current in the primary is made to vary rapidly in strength by means of some form of interrupter, thus producing rapid changes in the intensity of the magnetic field. This reacts upon the windings of the secondary and induces an electromotive force in each turn of the wire. At each make of the current in the primary coil a weak current flowing in the opposite direction is set up in the secondary; while at each break in the current there is induced in the secondary a strong current flowing in the same direction. This break current is the one used to excite the X-ray tube. If the make current is allowed to pass into the tube "inverse rays" are produced and the efficiency of the ray is greatly reduced.

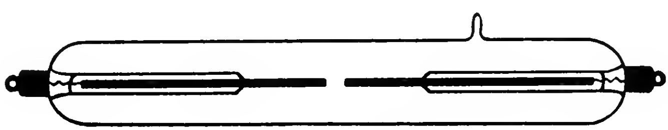


FIG. 11.—The oscilloscope.

INVERSE CURRENTS.—A tube in which the inverse current plays a part does not have the clear-cut hemispheres of a properly working tube, but will have one or more green rings back of the target.

The production of inverse currents can also be demonstrated by means of the oscilloscope (Fig. 11). When connected in series with a coil, if the current is unidirectional a violet band will be seen at the negative end, while if there are inverse currents bands of equal or unequal length will be seen at both ends.

Inverse currents may be prevented from entering the tube by introducing a spark-gap of such length that the make current is too weak to pass it.

Another method is to use the ventril or valve tube of Villard (Fig. 12). One pole of the Villard tube is made of a spiral of aluminum giving a large surface. This pole acts well as a cathode and permits currents to pass readily when it is the negative pole.

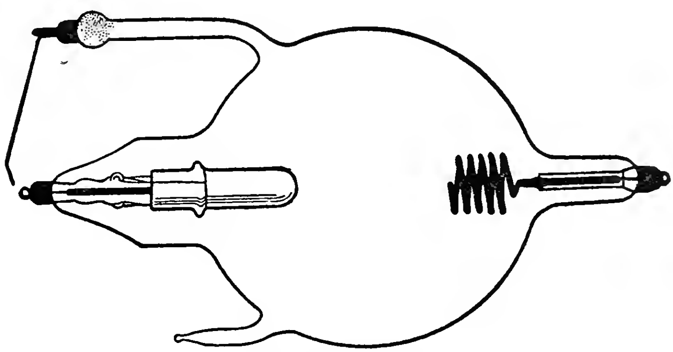


Fig. 12.—Valve tube.

As stated above, the secondary of the induction coil consists of many windings of very fine wire sometimes ten miles or more in length. It is usually wound in sections and these subsequently assembled. All the layers of the coil must be thoroughly insulated, each from the other.

The effect of the induction coil is to change a current of relatively low potential (110 volts) and high amperage (5–25) to a current of very high potential (100,000 to 150,000 volts) but of correspondingly low amperage.

THE INTERRUPTER.

Some means of interrupting the current must be supplied with the induction coil, for it is only by varying the number of lines of force surrounding the primary winding that a current can be set up in the secondary.

Interrupters may be classified as follows:

(1) MECHANICAL.

(*a*) *Vibrating.* This is the slowest.

(*b*) *Mercury.* Medium rate.

1. Dipper.
2. Rotary.
3. Jet.

(2) ELECTROLYTIC. Most rapid and therefore give the strongest current.

1. Wehnelt.
2. Caldwell-Simon.

VIBRATING INTERRUPTER.—This interrupter operates on the same principle as the electric bell, and consists essentially of a spring carrying at its end a platinum contact point and an armature of soft iron. The armature is close to the end of the induction coil. The instant a current flows through the primary of the coil the core becomes magnetized, and acting upon the armature of soft iron pulls the platinum contact point away from its contact with the general circuit. When this happens the circuit is of course broken and the core becomes demagnetized. The armature is no longer held against the core and the spring carries the platinum contact point back to its contact with the main circuit.

There are many modifications of the vibrating interrupter and in some form or other it has been very widely used with X-ray apparatus, but there are many objectionable features to all of them. The platinum points may become uneven or may fuse, the spring may break, and they are very noisy. They are still used to some extent with portable apparatus but practically never with stationary installations. It is quite probable also that the portable apparatus of the future will be some form of high potential transformer actuated by a gas engine, with which an interrupter is unnecessary.

Mercury Interrupters.—These give a medium rate of make and break and medium strength of current.

Dipper Mercury Interrupter.—The contacts are made by a metallic rod dipping into the mercury. The mercury should be covered with a layer of some nonconducting substance such as paraffin or alcohol so as to effectually prevent sparking. The shaft raising and lowering the metallic rod is operated by a motor connected with a shunt circuit.

Rotary Mercury Interrupter.—This consists of a turbine attached to a shaft which is rotated by a motor. There are platinum tips on the turbine and the interruptions are made by these entering and leaving the mercury.

The rate of interruptions with both of these interrupters is regulated by varying the speed of the motor.

Jet Mercury Interrupters.—A motor operates a pump which throws jets of mercury in opposite directions. These jets striking the armatures produce the contacts. By raising or lowering the armatures the strength of the current may be increased or decreased.

ELECTROLYTIC INTERRUPTERS. — These interrupters depend upon the fact that when a current of electricity is passed through a liquid and one of the metallic electrodes is very small the surface of this electrode becomes covered with a thin layer of gas which stops the flow of the current. As soon as the current stops the gas disappears and the current again flows. These interrupters give as high as 40,000 breaks per minute.

The Wehnelt Interrupter (Fig. 13).—The fluid in this interrupter is sulphuric acid diluted with six

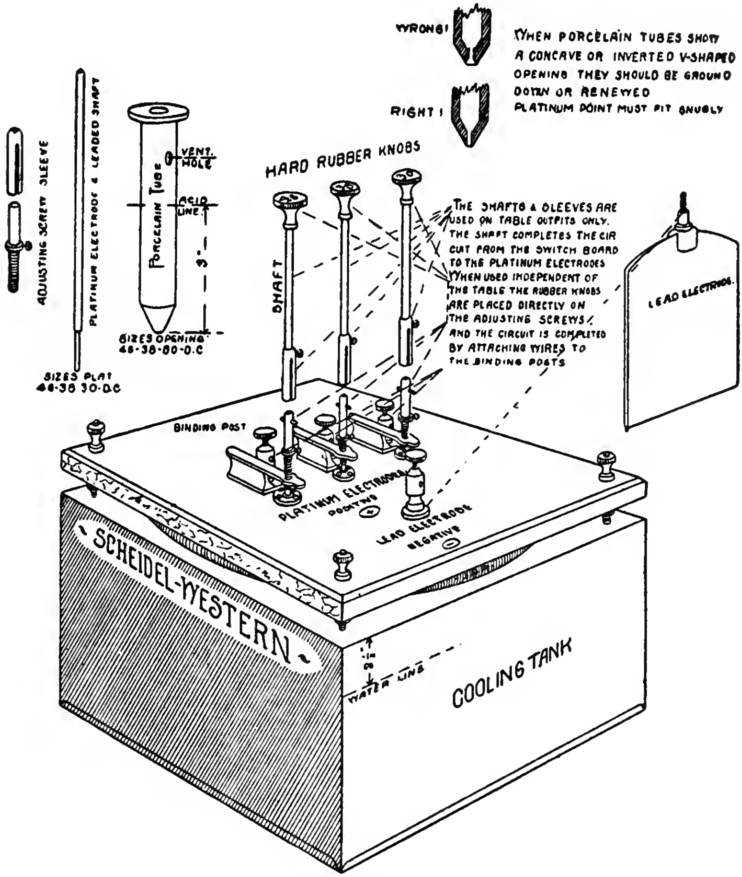


FIG. 13.—The Wehnelt electrolytic interrupter.

times as much water. The small electrode is of platinum, and the large one of lead. The platinum rod is enclosed in a porcelain sheath and by means of a screw a smaller or larger amount of the platinum may be made to project into the liquid. When a small amount projects the impulses are small and rapid, and when a larger amount projects they are heavier and less rapid.

The Caldwell-Simon Interrupter.—This has two large lead electrodes dipping into dilute sulphuric acid, the vessel containing which is divided into halves by a vertical partition. There are very small holes in this partition and when the current passes small bubbles of vapor are formed in them. This causes the break in the current. In this form of interrupter either pole may be the positive, while in the Wehnelt the platinum rod must always form the positive pole.

The electrolytic interrupter is the best for radiographic work while a mercury interrupter is better for fluoroscopy and for radiotherapy.

SOURCES OF CURRENT FOR OPERATING AN INDUCTION COIL.

(1) Electric Batteries.—All forms of batteries are objectionable because of the corrosive solutions they contain, and because of their rapid deterioration. They are practically never used in X-ray work.

(2) Storage Batteries.—The storage battery of an electric automobile will operate a coil and inter-

rupter. Small portable storage batteries may also be used. The greatest objections to the use of storage batteries for portable apparatus are their great weight and the difficulties of getting them charged.

(3) Electric Lighting and Power Circuits.—The 110 or 220 volt lighting circuit with direct current is the best available source of power for an X-ray coil. The alternating current of the same voltage is also often used but requires additional apparatus to render it unidirectional. This is described below. Another available source of energy is the 500-volt-power circuit.

Use of Coil with Alternating Current.—When only an alternating current can be obtained to operate a coil some means must be used to render it unidirectional. It is possible to use the Wehnelt interrupter for this purpose, but the platinum pole being the negative during one phase of the current gives it an undesirable polarity and causes its rapid destruction.

The aluminum cell rectifier is the device usually employed to rectify alternating currents for use with X-ray coils. This rectifier transmits about 90 per cent. of the current passing in one direction and almost none of that passing in the other. The rectifier consists of four glass jars containing a solution of

Rochelle salts (1 part water to 1 part saturated solution of Rochelle salts). Each jar contains a lead and an aluminum plate. The alternating current wires are connected as shown in Fig. 14. The wire which delivers the positive current is connected to the

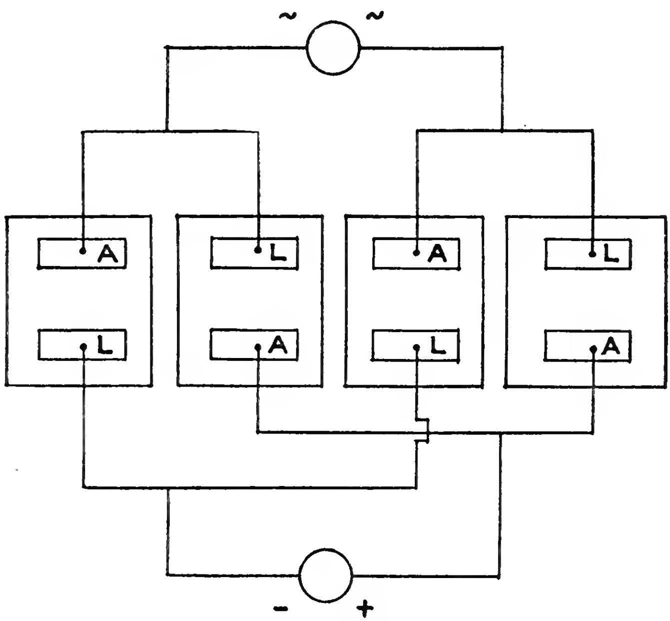


FIG. 14.—Aluminum cell rectifier.

aluminum of two cells and the negative wire comes from the lead of the other two cells. The current flows readily so long as it is passing from the lead through the solution to the aluminum, but not in the opposite direction, polarization preventing the flow in one direction while offering little obstruction to its passage in the other.

There are other forms of rectifiers for the alternating current, such as the mercury arc and mercury vapor vacuum tube rectifiers, but the one described above is the most commonly used at the present time.

The loss of power is so great with an alternating current that the direct current is always used to operate a coil if it can be obtained.

CHAPTER V.

Apparatus for Exciting the X-ray Tube (*Continued*).

High-tension Transformers.—The necessity for using some form of interrupter, and also a rectifier in the case of alternating currents, both containing some liquid, are disadvantages always encountered with coil apparatus. Even with the use of these appliances inverse currents often persist and cause rapid deterioration of tubes, besides making it difficult or impossible to obtain good pictures. For these reasons and because of its added efficiency, the type of apparatus known as a transformer is at present the most satisfactory for exciting the X-ray tube.

The transformer consists essentially of a primary and a secondary coil, both surrounding a continuous soft iron core. The principle is exactly the same as in the induction coil. With the latter, however, an interrupter must be used, while in the former an alternating current is utilized and the interruptions are supplied directly from the dynamo. The voltage of the secondary current depends upon the proportion between the number of turns of wire in the secondary to the number of turns in the primary. If, for instance, the secondary coil has twice as many turns as the primary then its voltage will be twice as great as that of the primary. It should be remembered that the amperage undergoes opposite variations at

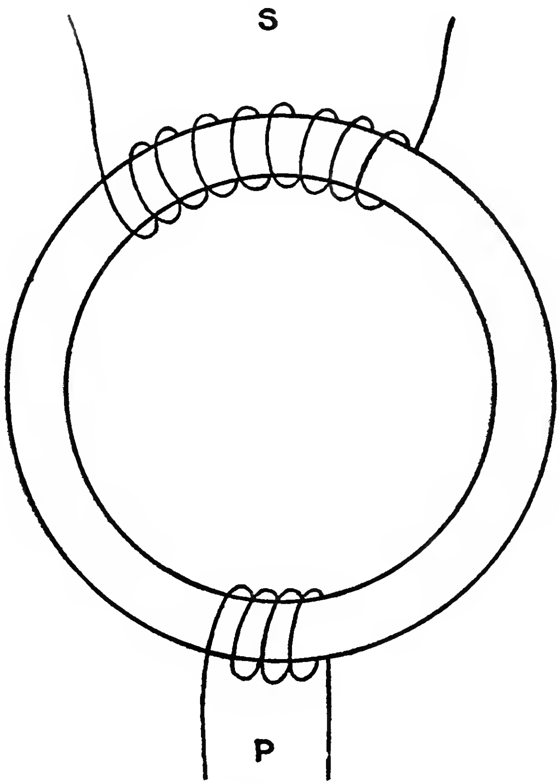


FIG. 15.—Ring type of transformer.

the same time. The transformer is a step-up or step-down transformer, depending upon whether the secondary has a greater or less number of turns than the primary. For X-ray work the step-up transformer is necessary. The ring type of transformer is illustrated in Fig. 15, showing the primary and secondary coils surrounding a ring-shaped core of iron. The transformer may be of the shell or jacket type, in which the primary and secondary coils are surrounded by laminated masses of iron, which, from an electrical standpoint, constitute the core.

The efficiency of the transformer is very high, being about 97 per cent. of the energy of the primary. The current furnished to the primary must be an alternating one. If only a direct current is available it must be changed to an alternating one by a motor generator. Operating the generator necessitates a considerable loss of energy, from 30 per cent. to 50 per cent. being lost in this manner. For this reason an alternating current supply is to be greatly preferred to the direct. It is necessary to use a motor even with an alternating current, for reasons which will be explained later, but this causes very little loss of energy.

The 220-volt alternating current is the ideal one for operating a transformer.

Thorough insulation of the primary and secondary coils is necessary. Some makers bury the coils in oil and others use only wax as insulation. The terminals of the secondary coil must also be insulated or separated to a considerable distance from each other, to prevent sparking across.

Methods of Rectifying the Current.—Just as the current passing through the primary of the transformer is an alternating one, so that in the secondary is of the same character. Before this current can be used to excite an X-ray it must be rendered uni-

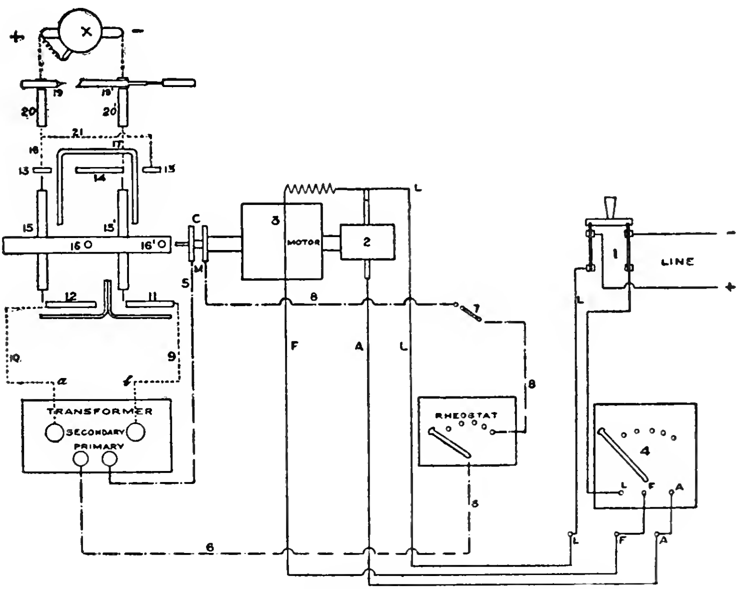
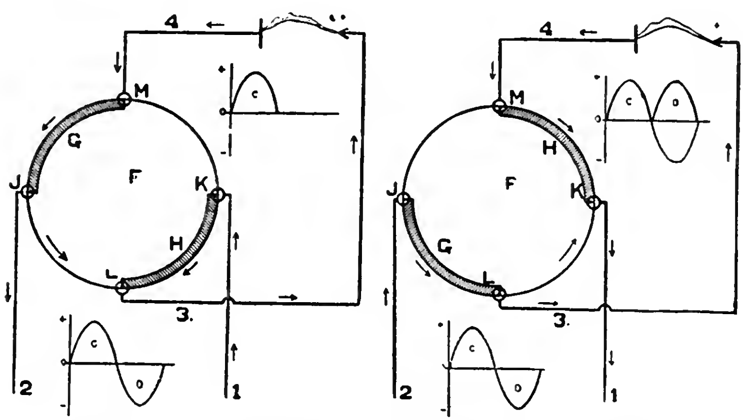


Fig. 16.—Diagram of connections of interrupterless apparatus.

directional by some means. Ventril or valve tubes, previously described, have been used for this purpose, but most high-tension transformers are now provided with some form of mechanical rectifying switches.

Fig. 16 represents diagrammatically the connections of the motor, transformer and rectifying switches of the so-called " interrupterless " apparatus used for X-ray work. A direct current is furnished from the line and passes through the switch 1, the line *L* to the armature 2, and the field 3 of the motor generator. From the generator the current returns through the wires *A* and *F* to the motor starter 4, and thence back through the main switch to the line. The motor starter is simply a resistance box and enables one to start the motor gradually. In the generator the current is changed to an alternating one, necessitating a considerable loss of power as mentioned above. This alternating current is taken off from the collecting rings *C* by the brushes *M*, passes through wire 5 to the primary of the transformer, through the windings of the primary to wire 6, through rheostat to wire 8, and the switch 7, back to the collecting ring on the motor. This complete circuit constitutes the primary circuit. The poles of the secondary coil are marked *a* and *b*. As previously stated, the current is here an alternating one, just as in the primary winding. Before it can be utilized to excite the X-ray tube it must be rendered unidirectional, this being accomplished by means of the four revolving arms 15, 15′, 16 and 16′. These arms are mounted on the same shaft as the motor, thus insuring that the revolutions of the rectifying arms are synchronous with the phases of the current from the motor. This is the reason also why a motor is used even with alternating currents, for if the current were taken directly from an alternating light or power circuit there would be no means of accurately synchronizing the revolutions of the rectifying switches with the phases of the primary current. The manner of operation of the revolving arms is as follows: When *a* is the positive pole of the transformer the current passes through wire 10 to the metal collecting ring 12, sparks across to the end of the copper wire on the revolving arm 15 which is then in position to transmit it, sparks across from this wire at the other end of 15 to the metal plate 13, and passes through wire 18 to the terminal 20 which is connected with the positive terminal of the X-ray tube. It then passes through the tube to the negative terminal (cathode), through 20′ and 17 to the metal plate 14, sparks across to 15′ and from 15′ to the metal plate 11, which is connected with the negative terminal *b* of the transformer. At the opposite phase of the current *b* is the positive terminal of the secondary and the current is conveyed through 9 to the plate 11; the shaft has now made a quarter turn and instead of 15′ being in position to convey the current, 16′ is now in position; the current therefore passes through 16′ to the metal plate 13′ and is conveyed through wire 21 to 18 and thence to the positive terminal of the tube, just as it was in the first instance when *a* was the positive of the secondary; the current then returns through 20′, 17, 14, and revolving arm 16, to 12 and thence to *a,* which is at this instant the negative terminal of the secondary. Thus both phases of the current are utilized, but it always passes through the tube in the same direction, no inverses being produced.



FIGS. 17 and 18.—Illustrating rectification of current by revolving discs.

Instead of using four revolving arms to rectify the current, a revolving disc on which are mounted two metal strips is used in some constructions, to secure a unidirectional current. Figs. 17 and 18 illustrate this method of rectification. *F* is a mica disc, *G* and *H* the two metal strips. *J* and *K* are the terminals of the secondary of the transformer. *L* and

M represent the brushes which receive the rectified current. In Fig. 17, if 1 is +, the current is taken up by the metal strip *H* and passes out through *L* to the anode of the tube. At the next alternation of the current the condition is shown in Fig. 18. No.

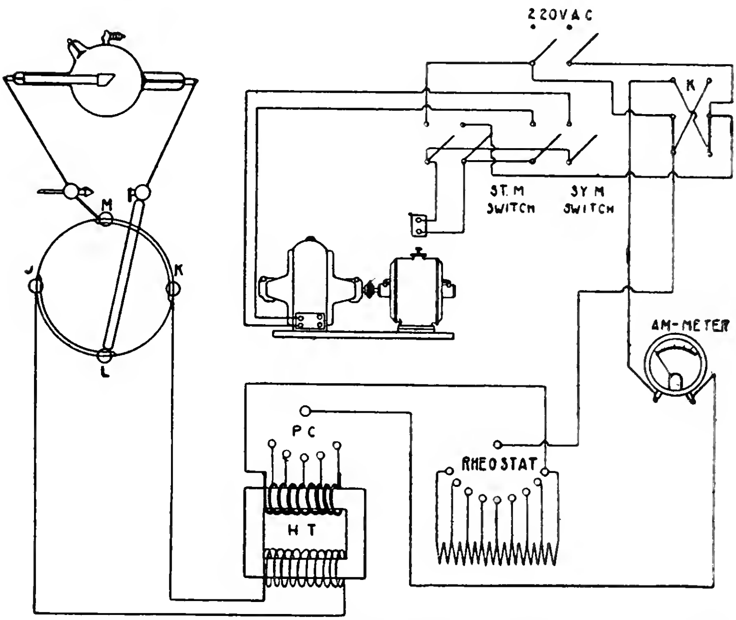


FIG. 19.—Diagram of connections of an "interrupterless" apparatus operating on an alternating current.

2 is now the positive and the metal strips have assumed the position shown by a quarter revolution of the disc; the current again passes through *L* to the anode of the tube. The arrows show the direction of flow of the current in each instance.

Both the system of the four revolving arms and that of the single revolving plate have been found in practice to be durable and efficient.

Fig. 19 is a diagram of the connections of an "interrupterless" apparatus operating on an alternating current. The main current flows directly from the line through the primary of the transformer instead of through the rotary converter as in the case of the direct current.

The two small motors, the starting motor and the synchronous motor, serve simply to revolve the rectifying disc *J M K*, the motors and rectifying disc all being mounted on the same shaft. The switch for the starting motor *S T M* is first closed, and when this motor has reached its maximum speed the switch to the synchronous motor *S Y M* is closed. The shaft is then revolving at the same rate as that of the dynamo in the power house which is the source of the current. This insures that the revolutions of the rectifying disc are exactly synchronous with the alternations of the current passing from the secondary of the transformer to the terminals *J* and *K*.

REGULATING THE CURRENT ON COIL OR TRANSFORMER.

Electric currents are controlled by means of resistance, the current strength being equal to the electro-motive force divided by the resistance (Ohm's law). Electrical resistance depends upon the material of which the conductor is made, the diameter of its cross-section, its length, and its temperature. Copper wire is one of the best practical conductors of electricity, iron wire not so good, and German silver one of the poorest. The latter is not used at all as a conductor but is very widely used as a resisting medium. The resistance of a conductor is directly proportional to its length and inversely proportional to the area of its cross-section or square of its diameter.

A rheostat is an appliance used to vary the strength of a current by changing the amount of the resistance. For X-ray apparatus, rheostats are usually made of a number of coils of German silver wire.

In Fig. 20 the dots represent contact-points to which the movable arm may be shifted. Nos. 1 and 2 are connected at the bottom, 2 and 3 at the top, and so on. The leading-in current enters at *H* and when the movable arm is set on the first contact point the current passes through *A*, down coil No. 1, up coil No. 2, down No. 3, and so on until it passes out at *B*. Shifting the arm to the second point eliminates coil No. 1 from the circuit and reduces the amount of resistance, thus increasing the strength of the current.

Resistance may thus be gradually reduced by shifting to successive points until the last one is reached and

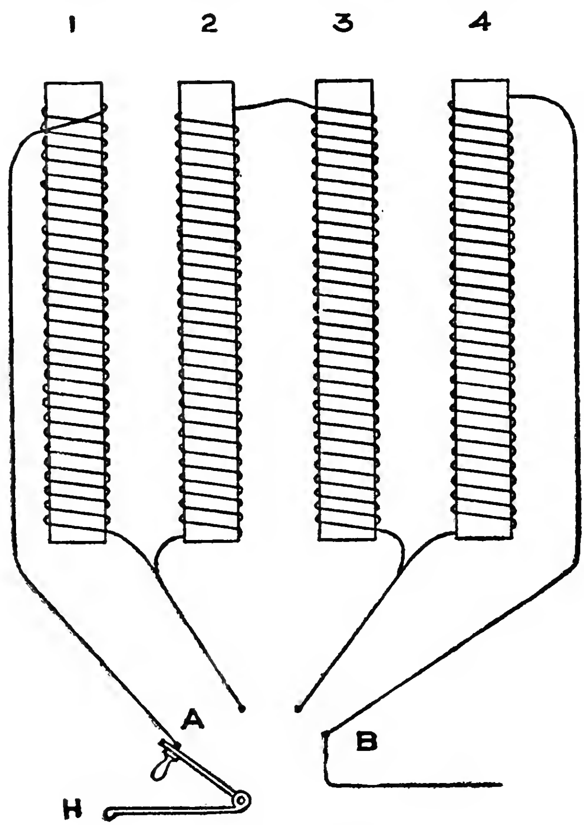


Fig. 20.—Rheostat.

the current flows directly from *H* through the movable arm to *B*, the rheostat no longer being in the circuit.

CHAPTER VI.

Radiography.

The X-ray acts upon sensitized plates like ordinary light, therefore the making of radiographs has much in common with photography. It must always be remembered, however, that whereas the photograph is produced by the action of light which is reflected from the object to be photographed, the radiogram, on the other hand, is a record of the penetrability of the different parts of the object to the X-ray.

The photographic plate consists of a piece of glass coated with gelatin containing sensitive silver salts. The salt may be either the bromide, the chloride, or the iodide of silver. The iodide is not often used except occasionally as an addition to the bromide, and the chloride is used only for slow emulsions such as are used on printing-out paper and for lantern slides. The gelatin-bromide emulsion, either with or without the iodide, is the one usually employed. The sensitiveness of the emulsion is governed by the manufacturer by the length of time during which it is subjected to boiling or other method of "ripening." The increase of sensitiveness is said to be due to the enlargement of the particles, something like the growth of particles by crystallization. The particles as they become larger are able to absorb more light and consequently a greater amount of silver is reduced, rendering the plate more rapid. A similar explanation is given as to why the amount of emulsion on the plate affects its sensitiveness.

X-ray plates differ from photographic plates only in their greater sensitiveness, the emulsion being thicker than on photographic plates.

The exact effect that light has on silver salts is not yet entirely understood. So far as known, light exerts a reducing effect on the salt, setting free the chlorine, bromine, or iodine. The latent image consists of some modification of the halogen.

In order to bring out the latent image some form of developer is necessary. A developer contains several ingredients known respectively as the reducer, the accelerator, the restrainer, and the preservative. There are a great variety of reducing agents, among which are pyrogallic acid, hydroquinon, metol, amidol, eikonogen, ortal, rodinal, etc. The function of the reducer is to reduce the exposed silver bromide to metallic silver, for it is this metallic silver that produces the lines of the picture. Most of the reducers named, however, will not act quickly enough by themselves, so that an accelerator must be added. Some alkali, usually sodium carbonate, fulfills this function.

The restrainer is added, usually potassium bromide, so that the developing may be more under control and not take place too rapidly. Sodium sulphite is usually added to act as a preservative, which it does by taking up oxygen and thus preventing oxidation of the reducer.

Following are some formulas for developing solutions:

HYDROQUINON OR QUINOL.

No. 1.	Hydroquinon	6	gm.
	Sodium sulphite	50	gm.
	Water	500	c.c.
No. 2.	Potassium carbonate	100	gm.
	Potassium bromide	1.5	gm.
	Water	500	c.c.

For use take equal parts of No. 1 and No. 2.

The hydroquinon developer may be made in one solution, according to the following formula, but should be made fresh for each day's work:

Hydroquinon	36	gm.
Sodium sulphite, dry	90	gm.
Potassium carbonate, dry	180	gm.
Potassium bromide	9	gm.
Water	1800	c.c.

Hydroquinon is a reducer which gives great contrast in pictures and since this is a very desirable thing in radiographs it makes a good developer in X-ray work. Where softer negatives with greater detail are desired metol is a valuable reducer. Hydroquinon and metol may be used together according to the following formula:

No. 1.	Metol	1 gm.
	Hydroquinon	4 gm.
	Sodium sulphite	50 gm.
	Potassium bromide, 10 per cent. sol.	4 c.c.
	Water	250 c.c.
No. 2.	Sodium carbonate	50 gm.
	Water	250 c.c.

Mix No. 1 and No. 2 in equal parts.

The advantages of having the accelerator, sodium carbonate, in a separate solution are that the developer keeps better and that development is better under control. If the plate is over-exposed then a small amount of No. 2 should be added; if under-exposed, a proportionately larger amount.

After the negative has been developed it is necessary to remove the silver from the unexposed parts of the film. This is known as fixing, and is effected by placing the plate in a solution of sodium hyposulphite, made according to the following formula:

A

Water	4000 c.c.
Sodium hyposulphite	1000 gm.

B

Water	1000 c.c.
Sodium sulphite, dry	90 gm.
Sulphuric acid	15 c.c.
Powdered chrome alum	60 gm.

Mix B in exactly the proportions and sequence given above.

Pour B into A while stirring. During cold weather one-half of B is sufficient for the full quantity of A.

TECHNIC OF RADIOGRAPHY.

The X-ray plate is placed in a black envelope, and the latter in an orange envelope. It is so placed that the film side of the plate is next to the smooth side of the envelopes, that is, the side opposite the flaps. The film side is recognized by its dull appearance and by the fact that the slightly moistened finger sticks to it. Some form of plate holder may be used instead of the envelopes. The plate is placed in its envelopes or plate holder in a photographic dark-room illuminated only by a good ruby light. All plates kept in stock should be kept in a lead-lined box in a cool, dry place, and should be put into envelopes or plate holder only immediately before use.

After being placed in its envelopes the plate is taken to the X-ray room and protected from the X-ray in a lead-lined box or behind a lead partition while the tube is being tried and regulated. When the tube is ready the plate is placed under the patient with its centre immediately beneath the centre of the part to be radiographed. The target of the tube is then centred over the centre of the plate at a distance of 18 to 25 inches from the plate.

No definite rules can be given for the time of exposure, since it differs with the strength of the current, the condition of the tube, distance of the tube from the plate, thickness of the part to be radiographed, and the sensitiveness of the plate. Every radiographer must determine the time of exposure for different parts of the body on his particular apparatus. By recording the reading of the milliammeter, the length of the parallel spark gap, the distance of tube from plate, and the thickness of the part, he will soon be able to estimate very closely the exposure time in each particular case. In general it may be said that the transformer with alternating current supply enables one to do the most rapid work while the transformer with direct current is next. Coil apparatus with direct current comes next to the transformer, while the coil with alternating current supply requires the longest exposures of all.

At the present time excellent intensifying screens made of calcium tungstate are to be had, and when properly used greatly shorten the time of exposure.

The screen should be brushed off carefully each time before using and should be placed in contact with the film side of the plate against which it must be snugly pressed while the exposure is being made. The ray must pass through either the screen or the plate to reach the film. The latter is the most common method. The screen enables one to take practically instantaneous pictures of the bismuth-filled stomach and colon and is indispensable for such work. It is not possible to obtain such fine detail with the screen, however, as without it.

After exposure the plate is taken to the dark room, removed from its envelopes, and placed in the developing solution. It should be slid into the tray of developer and the solution made to cover the entire plate immediately by a wave-like motion. It is important that the developer be kept at a temperature of about 65° to 68° F. All air bubbles should be removed from surface of the plate by rocking the tray. Complete development is judged by the even black appearance of the back of the plate when it is held up to the ruby light. When developed the plate is washed for a moment in running water and placed in the fixer. After it has remained in the fixer for about a minute the light may be turned on. The plate is fixed when all the dull white film has disappeared from it,—a fact which may be determined by looking at the back of the plate, but it should be left in the solution for about 15 minutes after this has occurred. When the plate is fixed it should be washed for at least an hour in running water.

Over-exposed Plates.—A plate on which the image flashes up almost immediately upon placing it in the developer is usually over-exposed, and if developed in the usual way would be so dense that the picture could scarcely be seen. It may be taken from the developer immediately and the process finished in a weaker developer, or a few drops of 10 per cent. solution of potassium bromide may be added to restrain the development. If after development the plate is still found to be too black and dense it may be greatly improved by treating it with a reducer. For this purpose the following solution may be used:

Potassium permanganate	.5	gm.
Sulphuric acid	1	c.c.
Water	1050	c.c.

Before treating with this reducer the plate should be washed but does not require to be entirely free from hypo. Rock the dish continually while the plate is in the reducer. If a stain is left by the permanganate it may be removed by a 1 per cent. solution of oxalic acid.

Potassium cyanide is often used as a reducer according to the following formula:

Potassium cyanide	1	gm.
Potassium iodide	.5	gm.
Mercuric chloride	.5	gm.
Water	300	c.c.

The plate must be well washed to remove the poisonous chemicals in the above formula.

Under-exposed Plates.—Plates that have had insufficient exposure will need to be developed for a long time in a strong developer. Leaving them in too long, however, will often fog them. Under-exposed plates may be much improved by treating them with an intensifying solution such as the following:

Mercuric chloride	11	gm.
Potassium bromide	6	gm.
Water	210	c.c.

Leave the plate in this solution until it looks white, then wash it in running water for about one-half hour. The plate is then placed in

Sodium sulphite	45	gm.
Water	180	c.c.

until it has turned black, and is then thoroughly washed.

Of course the ideal is to give the correct exposure and to develop to the proper density, but this is not always attained, and many otherwise valueless plates may be saved by reduction or intensification.

Practice is the only way to become proficient in taking and developing radiograms.

CHAPTER VII.

Fluoroscopy. Stereoscopic Radiography. Localization of Foreign Bodies.

FLUOROSCOPY.

The fluoroscopic screen is made of platinobarium cyanide crystals which fluoresce when the X-ray falls upon them. This screen may be fitted into the end of a light-proof box into which the observer looks, or built into other forms of apparatus. When a part of the body is held between the screen and the X-ray tube the rays pass with varying degrees of penetration. Around the part where there is no obstruction, they cause the screen to fluoresce very brilliantly; under the soft parts the fluorescence is less brilliant; and if the degree of penetration is too great there is no fluorescence at all beneath the bones, and they appear black.

The long exposures necessary for fluoroscopic work have made it a very dangerous method to the operator, a fact all-too-well proven by the loss of limbs and even of lives of radiographers. Apparatus is now built, however, so that fluoroscopic work may be done while the operator remains well protected even from secondary radiations.

It is essential for good fluoroscopic work that the voltage be as high as possible, but only a few milliamperes of current are necessary. The static machine is therefore ideal for this purpose. Satisfactory fluoroscopic work may be done, however, with either coil or transformer if they are equipped with some arrangement for delivering a very small current to the tube without lessening the voltage. Different manufacturers have accomplished this in different ways. Some makes of apparatus are so arranged that a variable number of windings of the primary may be used, others depend upon a choke-coil in which inductance reduces the current strength with practically no change in the voltage. Another arrangement, which has proven very satisfactory in operation, is the invention of Dr. Harry Waite of New York. It is essentially a revolving disc fixed upon the same shaft as the motor and the rectifying switches. A metal plate forms a quarter of the circle of this disc which is mounted so that three carbon brushes connected in the primary circuit press against it. The leads from these three brushes pass through a rocking switch and the connections are so made that when the switch is open only fifteen of the sixty cycles of the alternating current are transmitted; when the switch is closed on one side thirty cycles of the current will pass, while if it is closed on the other side the current is short-circuited through the switch and the full sixty cycles are transmitted to the tube. Excellent fluoroscopic work may be done with both the fifteen- and thirty-cycle current with very little wear on the tube.

The best field for fluoroscopy is the chest, in which the contrast between the different parts is great enough to render the shadows very distinct. The presence of cardiac hypertrophy or aneurism of the aorta is readily made out. Limitations in the excursion of the diaphragm may be seen and the extent of pleuritic effusion determined. Gross lesions of the lungs are rendered visible, but for the finer lesions fluoroscopy is much less valuable than radiography.

Fluoroscopy has also been found of considerable help in studying the movements of the stomach filled with a bismuth meal, and of the colon while giving a bismuth enema.

The operator should never lose sight of the danger of exposing himself to the X-ray, and should do fluoroscopy only under the most favorable conditions. The room should be completely darkened and the operator should remain in the dark at least three minutes before the ray is turned on. It is only by observing these two points that satisfactory fluoroscopic work can be done. The smallest current that will give distinct shadows should be employed and the opening in the diaphragm should be reduced to the smallest size practicable for the work in hand. For the safety of the patient it is important that the examination be made in as short a time as possible.

With the proper apparatus, and observance of the necessary precautions, there is no doubt that fluoroscopy will increase in value.

STEREOSCOPIC RADIOGRAPHY.

Radiograms are necessarily perfectly flat pictures, —that is, they give no perspective. It is often of the greatest advantage to be able to tell which parts in the picture project towards, and which parts away from, the observer. For this purpose stereoscopic radiograms are made. This is done by taking two pictures of the part, the plate for the second one being placed in exactly the same position as the first, the tube having been displaced laterally a short distance. Both pictures must be taken without any movement on the part of the patient. This procedure gives two pictures of the part, taken from slightly different view-points, which may be placed side by side and fused into one image by some form of reflecting or refracting stereoscope. The observer thus gets a sense of perspective, or depth, in the picture and sees all the parts in their proper relations.

The technic of making stereoscopic radiograms is not difficult. It is necessary only to have some form of plate-changing device so that the second plate may be substituted for the first without any movement of the patient, and such construction of the tube-holder as will provide for readily shifting the position of the tube. Most tables and tube-holders are now constructed to meet all the requirements of stereoscopic work.

The procedure in making stereoscopic radiograms is as follows: The part to be radiographed is placed firmly upon the plate-holder so that no movement will take place. A plate is placed in the plate-holder and the first exposure made. The plate is then removed and another placed in the holder in exactly the same position as the first one. The tube is then shifted to the right or left of its first position for a distance of about three inches, corresponding to the distance between the pupils of the eyes, and a second exposure made. When developed these two plates are placed side by side, and viewed with a stereoscope. Positives can then be made on one small plate and the pictures viewed conveniently through the common hand stereoscope.

Stereoscopic radiograms are invaluable in fractures and dislocations, the relation to each other of the fragments or displaced articular surfaces being shown accurately. The position of foreign bodies in relation to surrounding parts can be seen very clearly. The value of radiography in the diagnosis of intrathoracic disease has been increased greatly by stereoscopic work. Stereoscopic radiography has also been found of definite value in the study of the bismuth-filled colon. Study of the nasal accessory sinuses is also rendered much more intelligent if stereoscopic radiograms are taken.

No radiographer who has once recognized the immense improvement of stereoradiographs over the simple flat picture, especially in fractures, dislocations, and intrathoracic lesions, and in the study of the colon, will ever be content to rest a diagnosis upon the evidence furnished by the simple radiogram.

THE LOCALIZATION OF FOREIGN BODIES.

The image of foreign bodies in the tissues may be seen on the fluorescent screen, and also in simple radiograms, but it is often difficult to estimate their distance from the surface.

Many different methods have been used for the accurate localization of foreign bodies.

The Stereoscopic method has already been mentioned and is of undoubted value unless it is necessary to make an absolutely accurate localization.

The Triangulation method necessitates such complicated mathematical calculation that it is very little used.

The Mackenzie-Davidson method is probably the one most commonly employed and has been found perfectly satisfactory by the author. Briefly, it consists of making two exposures upon the same plate without any movement of the patient or the plate, the tube being shifted laterally a known distance for the second exposure. To carry out this method the plate is placed on the table beneath two crossed wires. One of these wires must be parallel to the horizontal bar carrying the tube, so that when the tube is displaced the focus point on the target will always be perpendicularly above a point in the wire. The focus point of the target is accurately centred perpendicularly above the point of intersection of the cross-wires. The tube is now displaced a known distance, two inches for instance, from the centre. The part to be radiographed is placed firmly upon the table. It is necessary to have the position of the cross-wires marked upon the patient's body, and this may readily be done by inking the wires, or when the patient arises by rendering the red marks left by the wires more permanent by the marks of an indelible pencil. It is also well to place a small lead marker on one corner of the plate and to mark its position on the patient's body. The first exposure is now made, and without movement on the part of the patient, or movement of the plate, the tube is shifted two inches to the other side of the centre and the second exposure made. The plate is then developed and shows the images of the cross wires dividing the plate into quadrants, two images of the foreign body, and the image of the lead marker which enables one to select the corresponding quadrants on plate and patient. The plate is placed on a table beneath a horizontal bar from which two threads are hanging. The bar is the same distance above the plate as the focus point on the target of the tube was in taking the pictures. The threads are fixed on the bar two inches each side of a point which is perpendicularly above the point of intersection of the image of the cross-wires on the plate, thus representing the target of the tube in its two different positions. Not only must the intersecting point on the plate be perpendicularly beneath the selected middle point on the bar but one of the cross-wires must be parallel to the bar.

The end of one of the threads is now placed upon a point in one image of the foreign body, and the end of the other thread upon the corresponding point in the other image. The point where the threads cross obviously represents the position of the foreign body in relation to the plate. A perpendicular can be dropped from this point to the plate and a mark made on the plate. If the foreign body is large, like a bullet for instance, each end of it can be localized in this manner.

The distance of the mark on the plate from the two cross-wires can now be measured.

The perpendicular distance of the point of intersection of the threads from the plate represents the distance of the foreign body beneath the skin which rests upon the plate. The marks of the wires being left upon the patient's skin it is only necessary to measure the distances found above from each wire. The point of intersection of lines representing these two measurements gives the point on the patient's body below which will be found the foreign body, at the exact distance ascertained above.

This method is rapid and accurate and requires no complicated mathematical calculations in its application.

For the localization of foreign bodies in the eye it is necessary to have some special form of apparatus. The localizer devised by Dr. Sweet, of Philadelphia, is the one used by the author, and has been found perfectly satisfactory. Detailed description of the method of using this apparatus can be obtained from the manufacturer and will not be included here.

CHAPTER VIII.

DISEASES AND INJURIES OF BONES AND JOINTS.

THERE seems to be little necessity for insisting upon the importance of X-ray examination of bone and joint lesions, for this is the field in which radiography has proven of the greatest value.

It should be an invariable rule to secure radiograms, not only in cases of undoubted fracture or dislocation, but in every case of injury to the bones. This is especially important when the injury is near a joint. The necessity for this is demonstrated by the great number of cases in which no clinical diagnosis could be made other than contusion or sprain, and in which the radiogram revealed a fracture or dislocation. Radiograms are especially valuable in bone and joint injuries to establish the presence or absence of a complicating lesion, such, for instance, as a fracture of the greater tuberosity or head of the humerus in shoulder-joint dislocations, or dislocations of the carpal or tarsal bones in injuries about the wrist or ankle.

In examining bones either for injuries or diseases it is always well, where practicable, to make radiograms from two different angles. The target of the

X-ray tube should be centred directly over the lesion to avoid the distortion which occurs if the picture is taken obliquely and which may give an entirely erroneous impression of the amount of overriding or separation of the fragments in fractures.

Stereoscopic radiograms are invaluable in determining the correct relation of the fragments in fractures and of the articular surfaces in dislocations.

No special instructions need be given for radiographing the different joints of the body, but a few practical points may be mentioned.

The *spinal column* in the lumbar and lowermost dorsal regions should be taken anteroposteriorly. The cervical region may be taken both anteroposteriorly and laterally. The thoracic spine shows very poorly in radiograms taken in the anteroposterior direction, and only fairly well in the lateral. It is possible, however, to secure good radiograms of it if the patient is turned partly on the left side so that the ray enters at a point about two inches outside of the right nipple and passes backward and to the left through the spine. This prevents superimposing the shadows of the sternum and the great vessels upon that of the spine.

The *shoulder* should be radiographed with the target centred over the glenoid cavity, the patient being in either the prone or supine position. Stereoscopic radiograms should always be made in cases of fracture or dislocation of the shoulder.

The *elbow, wrist, knee,* and *ankle* should be radiographed both anteroposteriorly and laterally. The side with the lesion should be placed nearest to the plate.

Radiograms of the *hip* are made with the target directly over the centre of the acetabulum, the patient usually lying upon the back. In interpreting radiograms of the hip it is important to remember that the arch formed by the under surface of the neck of the femur and the upper border of the obturator foramen normally make an unbroken curve. Good radiograms of the hip should show the posterior border of the acetabulum through the head of the femur.

DISEASES OF THE BONES AND JOINTS.

PERIOSTITIS and OSTITIS, whether of traumatic or infectious origin, are usually associated. Early in the disease when there is only periosteal involvement the only thing to be seen in the radiogram is a bulging in the contour of the bone at the site of the lesion. Later a distinct shadow is produced by the exudate thrown out, and later still the dense shadows due to sclerotic changes are seen.

OSTEOMYELITIS shows the exudative and sclerotic changes of periostitis and ostitis, but in addition, changes due to bone destruction are evident. Well-marked abscesses, and cavities due to necrosis, are present. In older cases sequestra are seen. The course of sinuses through the bone and soft tissues may be marked out by injecting bismuth paste. To show the exact course and relations of the sinus stereoscopic radiograms should be made.

Tuberculosis.—The distinguishing characteristic of tuberculosis of bone is the absence of lime salts, causing the shadow of the bone to appear faint and indistinct. It usually attacks the epiphyses and seldom involves the periosteum, the contrary being the case with syphilis.

Syphilis.—Bone destruction due to syphilis presents an irregular moth-eaten appearance quite characteristic of this disease. The periosteum is nearly always involved and sclerotic changes which produce dense shadows in the radiogram are always present.

Syphilis is distinguished from tuberculosis by these dense black shadows which are in distinct contrast to the faint shadows of the latter disease.

Osteomyelitis of non-syphilitic origin does not show such extensive periosteal involvement nor does it present the irregular moth-eaten appearance of syphilitic bone disease.

The shadow of osteosarcoma is considerably less dense than that of gumma. The most important distinguishing point between these two is that gumma remains confined to the bone and periosteum while sarcoma invades the soft tissues.

ARTHRITIS DEFORMANS.—The theory of the causation of arthritis deformans, which seems to be gaining rapidly in acceptance, is that the disease is of infectious origin, and that it is usually due to infection from some pre-existing focus in the body. According to this theory the disease may be due to the streptococcus, staphylococcus, gonococcus, or to any other organisms which may invade the joint, the pathological changes differing little with the various organisms.

This theory has now a large amount of clinical, and some experimental, evidence to support it.

The radiographic appearances vary greatly from almost no change whatever to extensive hypertrophic alterations. In the first class of cases there may be considerable swelling about the joint and the disease may run a chronic course, but the radiogram shows no change in the bones except a slightly decreased density.

Other cases have the characteristics of a productive osteitis. There is increased density in the ends of the bones, some exudate may be present, and there may be "lipping" about the joint. Any degree of these changes may be present up to the condition in which there is extensive bone formation about the joint, with great limitation of motion.

Spondylitis deformans, unless arrested, passes through all of the above stages, from that in which there is only slight irregularity along the articular margins to that of complete welding of the vertebræ by bridges of solid bone.

Exostoses are readily recognized in radiograms. They present themselves as irregular masses of osseous tissue springing directly from the bone and having a more compact appearance than normal bone. Exostoses give a much heavier shadow than osteosarcomata, and are more irregular in contour.

Enchondromata are most often found in the bones of the fingers and toes, but may occur in the long bones. They are often multiple, an important point in differentiating from osteosarcoma. These enchondromata have a transparent appearance but usually have small islands of osseous tissue or trabeculæ traversing them. They are distinguished from sarcoma by the fact that they are often multiple, have areas of osseous tissue, and that they do not invade the soft parts.

Osteosarcoma may be of periosteal or of myelogenous origin. These tumors have a pale, homogeneous appearance and regular, rounded margin. There is almost complete disappearance of the bony tissue, leaving in some cases a mere shell at the periphery. In the slower growing types there may be trabeculæ distributed irregularly through the tumor.

Bone-cysts and osteosarcomata are the two most difficult lesions to differentiate radiographically. Benign bone-cysts present a clean-cut translucent appearance, much like the early appearance of a slow growing sarcoma. The latter, however, is usually single while benign cysts are more often multiple. The sarcoma soon increases in size and encroaches upon the soft tissues and can then be differentiated from bone-cyst.

CHAPTER IX.

X-Ray Examination of the Head.

Fractures.—Lateral radiograms of the head show fractures of the vault very well, but it is only rarely that fractures of the base can be shown.

Fractures of the lower jaw can be shown quite plainly if care is taken to have the head in the best position and the rays passing at the correct angle. Fig. 21 illustrates the method used by the author. The fractured side should be nearest to the plate. The wedge-shaped block of wood shown in this illustration is useful for most head pictures and should be a part of the equipment.

New Growths.—Tumors of the bones of the skull or in the sinuses or orbit can usually be shown in a radiogram, but it is very seldom that much information can be gained concerning intracranial tumors. Tumor involving the pituitary body may cause absorption of the sella turcica and surrounding bony tissue and its presence diagnosed because of this.

The Accessory Sinuses.—Much valuable information may be gained by radiography of the nasal accessory sinuses. The correct relation of tube and patient is of the utmost importance in radiography of the sinuses.

The Frontal Sinuses.—The position of patient and tube is shown in Fig. 22. The patient's head is placed on the wedge-shaped block with forehead and tip of nose touching the plate. The target is centred over a point about midway between the occipital protuberance and the vertex. If the ray passes at a lower plane shadows of the heavy bones at the base of the skull will blot out those of the sinuses, and if a higher point is selected the shadows of the sinuses will be greatly distorted. Thickening of the mucous membrane causes a blurring of the shadow on the affected side, and the presence of pus, tumor, or granulation tissue renders the sinus so opaque to the ray that a dense white shadow is thrown. In the presence of symptoms of inflammation of the accessory sinuses radiographs are of immense help in locating the sinus involved. The presence or absence of one or both frontal sinuses may be established by good radiograms.

The maxillary antra may be radiographed with the tube in the same position as for the frontal sinuses, or with the ray directed at a point well below the base of the skull. Difference in the opacity of the shadows on the two sides is the point of importance in making a diagnosis.

The sphenoidal sinuses can be shown in radiograms, but it requires considerable skill in technic and experience in interpretation to be able to draw conclusions as to their condition. To study these sinuses Pfahler makes six radiograms, two postero-anterior, two lateral (stereoscopically), and two oblique.[1]

Dental Radiography.—There are two methods of making radiograms of the teeth, the intra-oral and the extra-oral method.

In the intra-oral method a small photographic film wrapped in black paper is placed inside the mouth, as nearly as possible against the teeth that are under investigation. In the extra-oral method the picture is taken upon an X-ray plate placed beneath the patient's head (Fig. 21).

In both methods the important point is to have the correct angle of incidence of the X-rays upon the film or plate. This is especially true of the intra-oral method. It is readily seen that in radiographing the teeth of the upper jaw the film cannot be placed parallel to the teeth. Its position depends upon the slant of the roof of the mouth. If the picture is made with the direction of the rays at right angles to the teeth they will appear elongated and distorted, while if the angle is too small the shadow of the teeth will be foreshortened. Fig. 23 illustrates the proper position for the majority of cases for radiography of the front teeth of the upper jaw.

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[1] The Amer. Quarterly of Röntgenology, November, 1912.

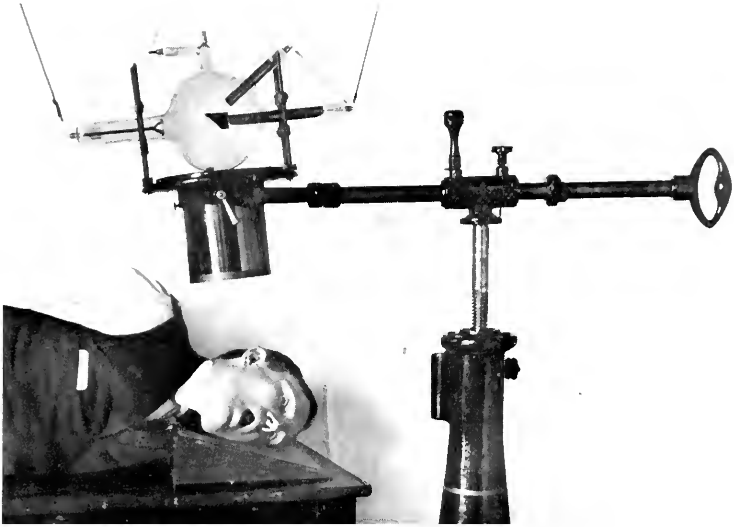

Fig. 21.—Position for lateral radiography of head.

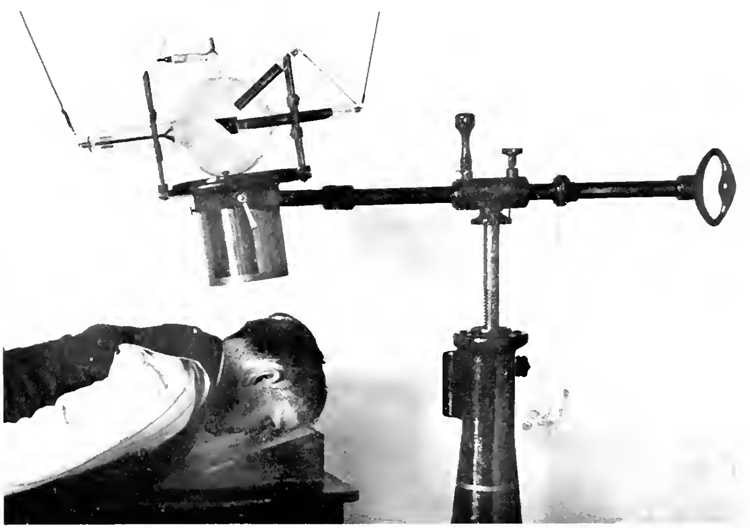

Fig. 22.—Radiography of frontal sinuses.

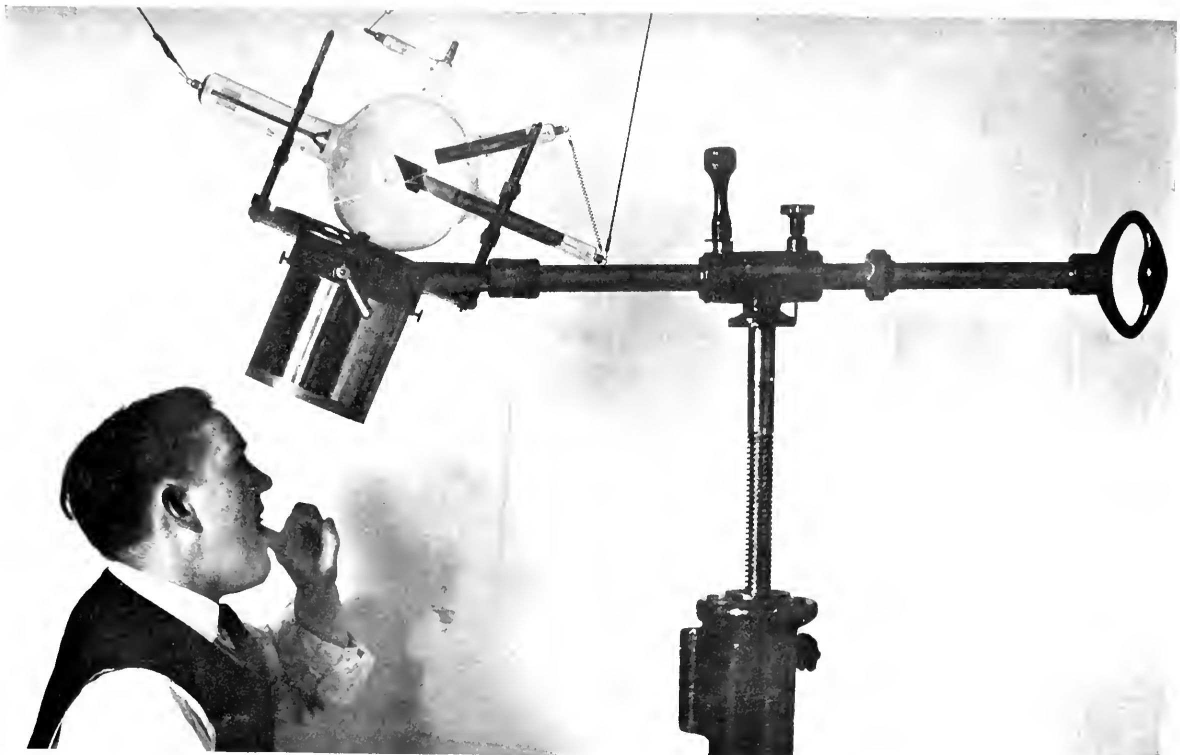

Fig. 23. Intra-oral method of dental radiography.

The intra-oral method is the best for all cases in which it is desired to secure detail about the teeth, but for fractures of either jaw, and in cases where it is necessary to show the relations over a wider area than can be covered by a film the extra-oral method is applicable. Fig. 21 illustrates the proper relation of the patient to the plate and tube in taking these pictures.

Good radiograms of the teeth and jaws give much valuable information in various abnormal conditions. Among these may be mentioned pyorrhœa alveolaris, localized alveolar abscess, the presence or absence and the position of unerupted teeth, the condition of root fillings and pivot teeth, and the presence of a foreign body such as a broken drill.

CHAPTER X.

The Thorax.

Fluoroscopy is of greater value in examination of the thorax than of any other part of the body because of the great contrast produced in the shadows by the air-filled lungs.

Some radiologists use fluoroscopy alone for examination of the thoracic organs, while others rely almost entirely upon radiography.

It seems the best practice to make use of fluoroscopy to determine the mobility of ribs and diaphragm, the presence of expansile pulsation in suspected aneurism, the presence of such gross lesions as pleural effusion or pneumothorax, and in a general way the aeration of different parts of the lung.

The fine details of lung structure, however, can be studied only in radiograms, so that it is necessary to make them both for purposes of diagnosis and in order to have a permanent record of the case.

The *technic* of radiography of the thorax is not difficult, but considerable care and experience are necessary to secure radiograms which give the greatest possible detail.

Stereoscopic radiograms are of immense value in diagnosing intrathoracic conditions, so much so that the author no longer makes single radiograms of the chest. In the stereogram every structure appears in its true relation to other structures, making it possible to avoid those mistakes in interpretation unavoidably caused by the superimposed shadows of the flat picture.

With the patient in either the erect or prone position the target of the tube is centred over the spinal column at the lower level of the scapulæ, the distance from the plate being at least twenty-five inches. The patient inhales deeply and the first exposure is made. While he holds his breath the tube is shifted three inches towards his feet, a second plate substituted for the first, and the second exposure made. The entire time for this complete operation ought not to be more than ten or twelve seconds, since some patients cannot hold the breath for a longer time.

For adults the plates should be 14 x 17 inches. Plates of such large size make the expense of stereoradiography a material consideration, but the added accuracy in diagnosis justifies the use of this method.

Screen Examination.—In studying the chest upon the fluorescent screen one of the first things to be observed is the movement of the diaphragm. Diminished excursion of the diaphragm is often found in diseases of the lungs and pleura (Williams' sign). This sign if present is of marked value in directing attention to early pulmonary tuberculosis, but it is too often absent even in advanced cases to be of great value.

THE HEART.—The size of the heart may be made out roughly on the screen or plate, and quite accurately with the orthodiagraph. In a short work of this kind space cannot be given for description of the latter method. Separation of the tube to a distance of five feet or more from the plate lessens the exaggeration so that it is almost negligible and one can arrive at a fairly accurate judgment of the size of the heart without orthodiagraphy.

An important feature to note is the angle formed by the right ventricle with the diaphragm, the cardiohepatic angle, which is obliterated in pericarditis with effusion but not in cardiac enlargements.

THORACIC ANEURISM.—The best position for screen examination is that with the ray passing from behind and the patient turned obliquely with the right anterior part of the chest pressing against the screen.

Care should be taken not to diagnose as aneurism the slight bulging of the aortic arch to the left which often occurs in normal subjects.

The diagnosis of thoracic aneurism is based upon the appearance of a large, smoothly rounded shadow in which expansile pulsation can often be detected.

Tumors of the posterior mediastinum are more likely to be irregular in outline rather than smooth like aneurism, and one may be able to distinguish the shadow of the normal aorta separate from the tumor.

Pneumothorax.—This condition is readily diagnosed either by screen examination or by radiography. The space filled by the air offers but little resistance to the passage of the ray, so that it appears very bright on the screen and perfectly black on radiograms. Another important point, and one which distinguishes pneumothorax from emphysema, is the absence of the lung markings over the area occupied by the air.

Pleurisy.—Acute pleurisy without effusion gives no radiologic evidence except limitation of movement of ribs and diaphragm. Pleurisy with effusion causes a dense shadow, which is first noted in the angle between the diaphragm and ribs. The fact that the density of the shadow is unaffected by respiration distinguishes it from pulmonary consolidations. If unencapsulated it may be distinguished from simple thickened pleura by its change in level upon change in position of the patient. Encapsulation is so common, however, that this is not a very valuable sign.

Pulmonary Tuberculosis.—The present estimation of the value of X-ray examination in pulmonary tuberculosis is well-stated in the following words: "although in the great bulk of cases, it (the stereograph) tells us no more than a careful clinical examination, yet in a fair number of cases, and these among the most interesting and puzzling, it gives additional information. But we must add the caution that a careful history is indispensable, since not even the stereograph can tell an active from a healed lesion."[1]

The first essential in studying pulmonary tuberculosis radiographically is experience in interpreting the shadows cast by the normal chest.

The dense shadow extending down through the middle of the radiogram is cast by the spinal column and sternum, the heart and large blood-vessels, the œsophagus, the trachea, lymphatics, and connective tissue.

On either side of the central shadow is an irregular shadow of less density, that of the hilus. This is cast by the primary branches of the pulmonary vessels with their contained blood, the walls of the primary bronchi, and lymphatic and fibrous tissue surrounding these structures.[2]

Radiating from the hilus are seen the shadows of the heavy trunks, three on the right and two on the left. The "fine linear markings" are seen to be subdivisions of the heavier trunks, the shadows of

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[1] Wolman, Bulletin of the Johns Hopkins Hospital, vol. xxii, No. 245, July, 1911.

[2] Dunham, *ibid.*

which disappear in normal cases before the periphery is reached.

It has been definitely proven by Boardman and Dunham [3] that the " linear markings " in the radiogram of normal lungs are a composite shadow of the artery and vein and their contained blood, the bronchus, and the supporting connective tissue.

Dunham [2] gives the following as the changes to be found in early tuberculosis:

1. Increase in area and density of the hilus shadow.

2. Small areas of great density in the hilus due to caseous, fibrous, or calcified glands.

3. Increase in density and breadth of the heavy trunks extending towards the diseased area.

The above changes may be due to mediastinitis or other conditions and are not typical of tuberculosis.

4. In the diseased area the fine linear markings are " broader, denser, and less regular in outline, frequently studded, almost to obliteration of the lines."

The markings are broken in continuity and extend to the periphery.

Interweaving of the lines to form a delicate mesh is quite characteristic.

As the lesion progresses the linear markings become more irregular, the studdings increase in size

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[3] Boardman and Dunham, *ibid.*

and density, the interweaving is closer, and the entire diseased area throws a shadow of increased density.

Dunham describes three branches in the upper lobes which show more plainly in disease than in health and in which the changes described above usually make their first appearance. One of these, the vertebral branch, passes upward from the hilus parallel with the spine, another passes outward behind the first interspace, and the third behind the second interspace.

Besides these changes in the lung markings, certain other signs of pulmonary tuberculosis have been described. One of these is limitation in diaphragmatic movement on the affected side. When present this is a valuable sign. Other signs such as the so-called "hanging heart," calcification of the costal cartilages, and the presence of narrow intercostal spaces, are of very doubtful value.

It should be remembered that pleuritic effusion often accompanies pulmonary tuberculosis and that it may be diagnosed radiographically when it has given no clinical signs. There seems little doubt that X-ray examination is a considerable aid in the diagnosis of early pulmonary tuberculosis, but here, as elsewhere, it must be used in conjunction with the history and all the other findings.

When the disease is advanced and can be diagnosed by clinical signs alone the X-ray is still of value in determining its extent, the presence of small cavities, etc. It is often the case that physical signs are present at only one apex when the radiogram shows a beginning lesion on the opposite side.

One of the principal difficulties is to distinguish an old healed process from an active lesion. A point of importance in this connection is the hazy, blurred appearance of the areas of active disease, in direct contrast with the clear-cut outlines of the healed lesions. It is often impossible, however, to decide between these from X-ray examination alone.

CHAPTER XI.

X-ray Examination of the Alimentary Canal.

The alimentary canal can be studied both fluoroscopically and radiographically by filling the lumen of the organs with some substance opaque to the ray. Bismuth in some form has been used more than any other substance. The subnitrate was formerly used, but its use has been abandoned because of some cases of poisoning thought to be due to the formation of nitrites. Bismuth subcarbonate is the salt now generally employed. Barium sulphate is also largely used and has the advantage of being very much cheaper than bismuth. Care must be taken, however, to secure a chemically pure barium sulphate. Such a preparation is now made by Merck especially for X-ray work.

When employing barium sulphate it is important to remember that it passes from the stomach in a much shorter time than bismuth subcarbonate and often does not give sufficient time for a thorough study of this organ. The author's custom is to use bismuth subcarbonate for administration by the mouth and barium sulphate for enemata.

The bismuth meal is prepared by mixing two ounces of the subcarbonate with six ounces of buttermilk, either natural or artificially made. Some other vehicle, such as cream-of-wheat or apple sauce, may be used if the patient objects to buttermilk.

This meal is given immediately before the X-ray examination is made, the patient having been prepared previously by a light diet for twenty-four hours and a saline laxative the evening before the examination.

A small lead marker should be fastened upon the umbilicus, and no more than one thin layer of clothing, without buttons or metallic fasteners, should be between the patient and the plate.

The Œsophagus.—Examination of the œsophagus is made both fluoroscopically and radiographically. Fluoroscopic examination is carried out by having the patient stand with his chest against the screen, the ray passing from behind. He is then rotated slightly toward his right so that the ray enters just outside of the angle of the left scapula and passes obliquely through the chest. This is the best position both for fluoroscopy and radiography of the structures of the posterior mediastinum.

To examine the œsophagus it is necessary for the patient to swallow a bismuth mixture. The passage of the bismuth to the stomach is followed on the screen and stoppage or deflection of the shadow noted. Normally the bismuth passes steadily down the œsophagus with sometimes a slight pause and backward deflection as it passes behind the arch of the aorta, with a little longer delay at the cardiac end.

Obstruction to the œsophagus may be caused by (1) pressure from without; (2) spasmodic or reflex contraction; (3) organic disease of the walls; (4) presence of a foreign body.

In order to differentiate the above conditions, great care must be exercised in studying the screen picture and in interpreting radiograms. Pressure from without may be due to aortic aneurism, mediastinal tumor, enlarged glands, or disease of the spine. Aortic aneurism and spinal disease can usually be diagnosed by X-ray examination, but the others are more difficult.

Obstruction from whatever cause unless relieved finally produces dilatation. Even cases of reflex contractions and cardiospasm in which no cause can be discovered often produce extreme dilatation (Fig. 24).

X-ray study of the œsophagus is very valuable to locate the site of an obstruction or dilatation and sometimes gives very definite information as to the cause. In this as in other parts of the body, however, the X-ray examination must be taken in conjunction with all the other findings, and great care must be exercised in interpreting the X-ray evidence.

Fig. 24.—Constriction at cardiac end of stomach. Note large amount of bismuth in lower end of œsophagus and the long stomach extending down into the pelvis.

THE STOMACH.—To study this organ by means of the X-ray several different methods and combinations of methods are advocated. Some radiologists use only the fluoroscope, to the complete exclusion of radiography. This is more common in Europe than in America. Others use only the radiographic method with patient erect or prone, while still others employ both fluoroscopy and radiography. The author's routine is to give the bismuth meal, and then with the patient in the prone position to take several radiograms, varying from six to ten, at intervals of three to five minutes, depending upon the rapidity with which the stomach empties itself. One or two radiograms are then taken in the upright position, and finally the action of the stomach is observed on the screen. Another radiogram is made after an interval of six hours to determine the time it takes for the stomach to completely empty itself.

The *appearance of the normal stomach* varies considerably in different individuals and in the same individual as a result of different postures, pressure, etc.

The most important region for study is that of the pylorus, including the terminal portion of the stomach, the region of the sphincter, and the first part of the duodenum. This latter plays a very important part in X-ray diagnosis of stomach, duodenal, and gall-bladder conditions. Because of the way it is placed with relation to the pylorus it is called the "cap." Figs. 25, 26, 27, and 28 illustrate the different appearances of normal stomachs and duodenal caps.

The gastric and duodenal surfaces of the normal cap should be smooth and regular, and the lumen centrally located. Deformity or malposition of the cap is one of the most constant of the radiologic evidences of adhesions, which may be due to gastric or duodenal ulcers or to gall-bladder disease.

The following radiologic indications of adhesions are given by Cole:[1]

1. The lumen varies in diameter, but does not dilate to the normal size.

2. The rugæ show unusually distinctly, have a crinkled appearance, and run obliquely or transversely.

3. The peristaltic contractions are clear-cut in the normal portion, but cease or are distorted when they reach the adhesions.

4. The cap is constricted, asymmetrical, displaced, or absent.

5. The duodenum is angular or contracted.

Figs. 29, 30, and 31 illustrate cases with adhesions due to various causes.

Gall-stones, unfortunately, only rarely cast shadows, but adhesions due to gall-bladder disease can often be diagnosed. In these cases the malforma-

[1] Cole, Archives of the Röntgen Ray, October, 1912.

FIG. 25

FIG. 26.

Types of normal stomach and duodenal cap.

Fig. 27

Fig. 28

Types of normal stomach and duodenal cap

Fig. 29.—Small deformed cap due to adhesions accompanying cholecystitis.

Fig. 30. Extensive adhesions of pyloric end of stomach due to large ulcer.

FIG. 31.—Adhesions causing distortion of cap; result of old ulcer.

FIG. 32.—Carcinoma of stomach.

tion of the cap may be only on the right side, and the cap itself, instead of being placed centrally upon the pylorus, is likely to be angulated. The entire pyloric region of the stomach may be more or less fixed at a point considerably farther to the right than usual.

CARCINOMA OF THE STOMACH (Fig. 32) gives a very characteristic picture in advanced cases, and even in early cases it is quite often possible to make a diagnosis of the presence of adhesions with very probable beginning carcinoma. The diagnosis is based upon irregularity in the outline of the stomach appearing constantly on the screen and on successive plates. "The lumen of the stomach is encroached upon by a nodular growth in the wall of the viscus, with islands or projections into the normal tissue, giving the appearance of finger-prints. The line of invasion may have a worm-eaten appearance with overhanging edges, or the growth may progress in the form of a cone, terminating at its apex in a small constricted lumen, which may be reduced to one-eighth inch in diameter, and filled with bismuth or entirely obliterated."[1]

Functional and organic hour-glass contractions of the stomach are often difficult to differentiate. The spasmodic constriction which most often occurs about the junction of the upper and middle thirds of the stomach may be purely functional, or may be due to a reflex contraction caused by ulcer, or it may be a true organic condition. Ulcer may be quite certainly diagnosed at the site of a spasmodic constriction if clinical signs and symptoms are present, but not otherwise. To differentiate the spasmodic from the real organic hour-glass stomach it is necessary to observe the screen shadow for some time or to take a series of pictures at rather long intervals. If the contraction is only spasmodic, relaxation may occur after a time, especially if massage is practised, while the organic contraction remains constant.

Cole gives the following distinguishing points between carcinoma, hour-glass constriction, and adhesions[1]:

Carcinoma.	Hour-Glass Constriction.	Adhesions.
1. The lumen of the constricted area is constant in size, shape, and position.	1. The lumen of the constricted area is constant in size and shape, but not necessarily in position.	1. The lumen varies in diameter, but never completely expands or contracts.
2. The growth is relatively wide.	2. The area or constriction is relatively narrow, or ring-like.	2. The area or involvement may be extensive or localized.
3. The rugæ are absent.	3. Peristalsis is present in either or both segments and the ring very closely resembles a peristaltic contraction.	3. The rugæ show unusually distinctly, generally running transversely or obliquely.
4. The peristaltic contractions are absent.	4. The line of involvement is smooth, and shows no evidence of nodular indentations.	4. The peristaltic contractions in the involved area are wider than normal.
5. The line of invasion is characterized by nodular indentations similar to finger-prints.		5. The line of invasion may be sharp or serrated, and shows no nodular indentations.

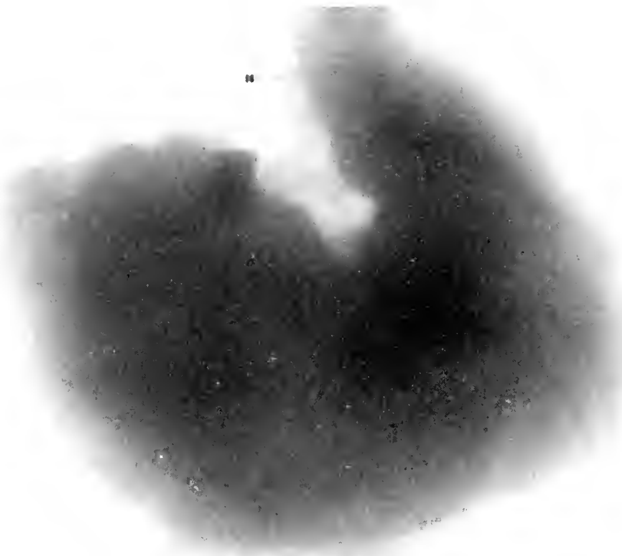

FIG. 33.—Obstruction at pyloric end of stomach, probably carcinoma

FIG. 34.—Angulation of cap and "under-shot" appearance of stomach.

FIG. 35 Enlarged and prolapsed stomach.

FIG. 36 Enlarged stomach

Pyloric obstruction (Fig. 33) may be diagnosed radiologically by the occurrence of exaggerated peristaltic action, the retention of bismuth for longer than six hours when the peristaltic action is good, and by a characteristic "under-shot" or prognathous appearance of the stomach (Fig. 34).

In judging the length of time that it takes for the stomach to empty itself care must be taken that no food is introduced into the stomach between the time of the bismuth meal and the taking of the second radiograms some hours afterward. If food is taken it mixes with the bismuth still present and causes its retention much longer than would be the case otherwise.

Other facts that may be determined readily with regard to the stomach are its size (Figs. 35 and 36) and its position (Fig. 37).

THE DUODENUM is not so readily studied radiologically as the stomach, because of the rapidity with which the food passes through it. It has been observed by many radiologists, however, that unusually rapid emptying of the stomach takes place in the presence of duodenal ulcer. This accords with the author's experience and it may be said with confidence that this is a valuable confirmatory sign of ulcer of the duodenum. In these cases the stomach may completely empty itself in from one-half hour to an hour.

Obstruction in the duodenum may be due to spasm caused by ulcer, or to adhesions. It may be shown in the radiogram by an enlargement of the bismuth shadow (Fig. 38).

The normal JEJUNUM and ILEUM do not yield much information from X-ray study because of the rapidity of the passage of the food and the superimposing of the shadows of the various coils.

Obstruction at any point is shown by an accumulation of the bismuth.

Kinks and constrictions in the terminal ileum often show quite plainly in radiograms.

THE COLON.—The large intestine may be studied after the administration of a bismuth meal or by giving an enema.

The author's practice in preparing the enema is to mix six ounces of barium sulphate with one and one-half to two liters of warm water, to which is added one ounce of powdered gum arabic to assist in keeping the barium sulphate in suspension. The patient is placed on his side with the hips slightly elevated and the suspension allowed to flow into the bowel very slowly through a tube introduced to a distance of six or eight inches. When the entire amount has entered the patient assumes the knee-chest posture for about three minutes and then lies upon the right side for about the same length of time.

FIG. 37.—Ptosis of stomach, patient erect.

FIG. 38.—Obstruction in second part of duodenum.

Fig. 39.—Colon and sigmoid with patient prone.

Fig. 40.—Same case with patient erect. Note redundancy of sigmoid with patient prone and the pressure of the transverse colon upon the sigmoid with patient erect.

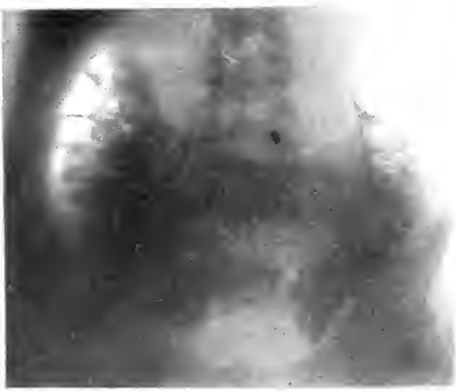

Fig. 41.—Dilated cæcum.

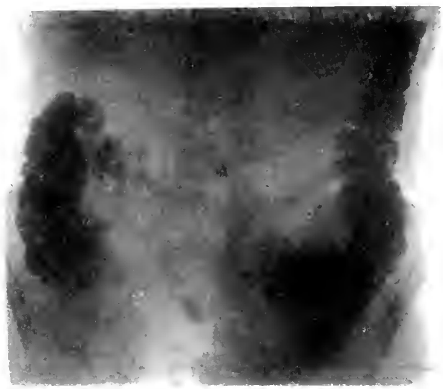

Fig. 42.—Same case after operation (plication), showing much smaller cæcum.

The above procedure secures the complete filling of the colon, including the cæcum, in practically every case.

The average time for the bismuth to reach the cæcum after the meal is about four and one-half hours, and it is usually through the sigmoid within twelve hours.

If kinks or constrictions are discovered it is well to confirm their presence by an examination made after an enema.

Stereoradiograms are often of great aid in deciding upon the true position of different parts of the large intestine, especially the relation of coils of the colon to the sigmoid.

The position of the colon with the patient prone often corresponds to the text-book pictures, but varies greatly with the patient erect.

Ptosis of the Colon (Figs. 39 and 40).—Even in normal cases the transverse colon makes a considerable downward curve when the patient is erect, but in cases of ptosis both the hepatic and splenic flexures may descend and the transverse colon may be well down in the pelvis.

The colon is a very movable viscus and it is often of great importance to determine whether some seemingly abnormal position is a fixed one. This may be done by taking pictures both in the horizontal and erect positions after the bismuth meal, and confirming these findings by examination after an enema.

The cause of constipation may be found in a kink or constriction at any point in the colon; in a large, dilated cæcum; in a long, redundant sigmoid; or in ptosis of the transverse colon pressing upon the sigmoid (Figs. 39 and 40).

Sometimes it is found after an enema that the bismuth passes back through the ileocæcal valve and fills from a few inches to several feet of the ileum. The exact importance of this is not yet fully understood.

The vermiform appendix sometimes fills with the bismuth and shows plainly in the radiogram. No importance is attached to this by the majority of observers.

CHAPTER XII.

The Urinary System.

Fluoroscopy is of very little value in examination of the urinary system. Radiograms furnish the only reliable evidence upon which to base either positive or negative diagnoses.

Technic of Examination.—The most pains-taking care in technic is necessary in radiography of the kidneys, ureters, and bladder.

The first essential is the thorough preparation of the patient, without which X-ray examination is valueless. A very light diet should be taken for twenty-four hours previous to the examination, and the bowels should be thoroughly cleared by means of aperients. An enema should be given shortly before the examination is made. Fecal shadows make it very difficult to arrive at correct conclusions, and for this reason it is often necessary for the patient to continue on a restricted diet for an additional twenty-four hours and to undergo a second preparation by means of purgatives and enemata. The best of technic will fail to produce satisfactory results if the patient is not thoroughly prepared.

The examination should include a radiogram of each kidney region, one covering the course of each ureter, and one of the pelvis, five in all. This is always necessary because it has often happened that the radiogram showed the stone in the opposite kidney from the one suspected, while in other cases there may be calculi on both sides. The pelvis must be included because the stone which has caused the renal symptoms may have passed into the bladder.

Plates 8 x 10 inches in size have been found the most satisfactory because their area can be completely covered by the ray with the use of a rather small cylindrical diaphragm.

A soft tube with sharp focus and having clear-cut hemispheres should be used. A tube which is too hard fails to give the detail in the soft structures essential to a good radiogram of the kidney regions, and may fail to show the softer calculi.

Compression by means of some form of compression diaphragm, rubber bag, or other apparatus is a valuable aid in securing good detail, because it displaces the abdominal contents over the kidney.

The plate for the kidney should be so placed that the last two ribs and the first three lumbar vertebræ will show upon it. The target is adjusted over the centre of the plate at a distance of about eighteen inches, and the exposure made while the patient holds the breath.

The essential features of a satisfactory radiogram of the kidney region are that it shall show clearly the last two ribs, the three upper lumbar vertebræ including the transverse processes, the outline of the psoas muscle, and the crest of the ilium. It is now often possible to show the outline of the kidney itself. It is important to use every effort to do this, for if a radiogram gives sufficient detail to show the kidney a negative diagnosis of calculus can be based upon it with only very slight probability of error. Even in very fat patients with thorough preparation and the use of good compression the kidney shadow may be shown.

The plate for the ureter should show the third, fourth, and fifth lumbar vertebræ and the sacro-iliac synchondrosis, while that of the pelvis should include both sacro-iliac synchondroses, the sacrum, and the coccyx to its tip.

Calculus.—The greatest value of radiography of the urinary tract has been in the diagnosis of calculus. Formerly it was thought that only a positive finding was of value, but with improved technic such fine detail can now be obtained that the errors in negative diagnosis are very few.

The positive diagnosis of renal calculus is based upon the presence of a definite shadow over the kidney region. If the shadow of the kidney itself shows on the plate no difficulty is experienced in locating the stone either in the pelvis or cortex of the kidney. The shadow is sometimes between the eleventh and twelfth ribs but more often below the twelfth rib. If the kidney is in its normal position the shadow is always internal to a line erected perpendicularly from the middle of the iliac crest.

A stone in the ureter produces a shadow somewhere along the line of the tips of the transverse processes of the lumbar vertebræ or over the sacro-iliac synchondrosis. In the great majority of cases it lies below the pelvic brim.

Differential Diagnosis.—Calcareous glands resemble calculi but may be distinguished from them by their more irregular outline and the fact that they are not usually over the course of the ureter.

Small calcareous bodies called phleboliths sometimes appear along the lower part of the ureter, but they are usually multiple, and may be arranged in a line at an angle to the course of the ureter.

Fecal concretions or foreign bodies in the intestine are distinguished from calculi by the fact that they change position or disappear entirely if several examinations are made.

Gall-stones only rarely throw dense enough shadows to be seen on the radiogram and when they do they usually have a fairly characteristic appearance. Because of the greater density of the outer layer of the stone the shadow has a ring-shaped appearance with a dark centre. Gall-stones may also be distinguished from renal calculi by the fact that they show much better when the patient lies with the abdomen next to the plate, while renal calculi cast their sharpest shadow with the patient on the back.

Difficulty in the diagnosis of renal calculus may arise because of displacement of the kidney from its normal position. The kidney may then be located by the injection into the pelvis through a ureteral catheter of some form of silver preparation such as collargol.

Sometimes a calcareous gland or other calcified body may throw a shadow directly on the line of the ureter. It then becomes necessary to take other radiograms with a bismuth-impregnated ureteral catheter in position. It must not be inferred, however, that a shadow is not that of a ureteral calculus simply because the catheter can be passed beyond it, for this has frequently happened. Radiograms at different angles and also stereoradiograms will need to be taken to establish the exact relation of the shadows.

The pelvis may be radiographed with the patient lying upon his back or upon his abdomen. If the latter position is used it is well to tilt the tube so that the rays pass obliquely forward and toward the patient's head. This prevents superimposing the shadow of the sacrum upon the region of the bladder.

Radiography is of great value in cases of vesical calculus, since it not only reveals the stones which might be discovered by the sound, but also shows the presence of stones which are encysted and cannot be discovered by the sound.

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