and beauty, being in the heart of the Cumberland Mountains, at an elevation of over two thousand feet above the sea-level, and surrounded by a vast natural park of pine trees. The pure air and equable temperature, as well as the isolation from the thoroughfares of travel, combine to render the location one of exceptional freedom from the ills of hot weather. A comfortable hotel, with ample arrangements for the comfort of guests, is at hand. The surrounding forests, hills, and fields offer many attractions for the botanist, the naturalist, and the sportsman. The following analysis was made by Dr. Robert Peter: One United States gallon contains: Iron carbonate, gr. 0.84; calcium carbonate, gr. 2.58; magnesium carbonate, gr. 0.86; calcium sulphate, gr. 0.17; magnesium sulphate, gr. 0.12; sodium sulphate, gr. 3.09; sodium chloride, gr. 0.15; silica, gr. 0.74. Total, 8.55 grains. A considerable quantity of free carbonic acid gas is also present.

The waters of the springs have been in use since 1843. They are said to possess excellent tonic and diuretic properties. It is also maintained that the location is very beneficial for cases of hay asthma, nasal catarrh, laryngitis, etc. *James K. Crook.*

ROCK ENON SPRINGS.—Frederick County, Virginia.

Post-Office.—Rock Enon Springs. Hotel.

Access.—Viâ Valley Branch of the Baltimore and Ohio Railroad to Winchester, thence by coach over picturesque mountain road sixteen and one-half miles to springs. Time from Washington, six and one-half hours.

This resort is located in the great North Mountains. It is surrounded by the primeval forest, and nestles under the shadow of a majestic peak in a romantic gorge, through which flows Laurel Brook, a beautiful stream which is supplied by the mountain springs, and which winds about the hotel and its attractive lawn. The locality is free from swamp lands and malaria. The hotel has a location of twelve hundred feet above tide water. This is a model caravansary, and the visitor may feel assured that every device for his comfort, health, and amusement has been arranged for by the thoughtful proprietor. The scenery in the neighborhood is exceptionally fine. Close to the hotel are three mineral springs, which have been found to possess well-marked medicinal properties.

The *Chalybeate Spring* was analyzed by Professors Gale and New, of the Smithsonian Institute, Washington, who found it to contain, in one United States gallon, the following solid constituents: Sodium carbonate, gr. 1.21; calcium carbonate, gr. 5.13; calcium sulphate, gr. 3.56; magnesium sulphate, gr. 12.89; magnesium chloride, gr. 1.12; iron oxide, gr. 14.25; manganesium oxide, gr. 1.05; alumina, gr. 0.80; silica, gr. 0.42. Total, 40.43 grains.

The water resembles that of the Pyrmont Spring in Waldeck, Germany. It is a strong chalybeate, and possesses aperient and diuretic properties.

A qualitative analysis of the *Alkaline Spring* by Professor Lupton, late of the University of Virginia, showed the presence of potassium and magnesium carbonate, sodium chloride, calcium sulphate and carbonate, silica, and carbonic, sulphuric, and hydrochloric acids. The water is antacid, diuretic, and aperient, and is used in affections of the kidneys and urinary passages, in dyspepsia, in gout, and in catarrhal affections.

The *Old Capper Spring* once gave its name to the resort, and it is styled Capper's Springs in the older books. It has been in use for more than a century. The water is described as being efficacious in rheumatism and in diseases of the skin, and as a cure for certain of the intestinal worms.

White and blue sulphur springs of excellent quality are also found in the neighborhood. The following data show the mean temperature at Rock Enon for July and August during the past ten years: July, 7 A.M., 66° F.· 12 M., 77°; 3 P.M., 78°; 6 P.M., 75°; and 10 P.M., 66.25°. For August, at the same hours, the record was 64.5°, 74.5°, 76°, 73°, and 66° F. *James K. Crook.*

RODENT ULCER. See *Carcinoma of the Skin.*

ROENTGEN RAYS, USE OF, IN MEDICINE AND SURGERY.—The discovery by Wilhelm Conrad Roentgen, in 1895, of the kind of radiant energy now known as the Roentgen or *x*-rays, was at once recognized as giving a most important addition to the armamentarium of the diagnostician in surgery. With improved apparatus and technique, and with more extended experience, the application of the Roentgen rays has gradually extended until their use is now universally regarded not only as indispensable in surgery, but as most valuable for diagnosis and therapy in many diseases not classed as surgical.

Nature and Action of the Roentgen Rays.—The Roentgen rays are produced by the passage of an electrical current of *small volume* and *high tension* through a specially constructed vacuum tube of high exhaustion. If an electrical current is passed through a glass tube from which the air has been but partly exhausted, an arc of light will be projected from the cathode (negative pole) to the anode (positive pole). If a similar tube of high exhaustion is used, no arc of light will form, but a peculiar fluorescence will appear at the anode. This fluorescence appears to emanate from any body exposed to the cathode of a vacuum tube. In the ordinary Roentgen-ray tube, the anode is a platinum plate placed in a line with the cathode, and the electrical energy passing from the cathode falls upon the anode, and from thence both fluorescent and Roentgen rays are projected. If the cathode is concave and directed toward the side of the tube, fluorescence will appear to emanate from the side of the tube at the point toward which the cathode is directed. Not only does the body fluoresce upon which the cathode rays are directed, but it will glow with heat if the electrical current is strong. In consequence, if the cathode rays are directed toward the side of the vacuum tube, the tube will become heated at the point of impingement, will soon soften and be destroyed by the giving way of the melted glass. For this reason the cathode rays are in practice directed toward a platinum plate which forms the anode, and which is set at an angle of about 45°, so that the Roentgen rays are directed from it outward at about a right angle to the long axis of the tube (Fig. 4114).

The visible fluorescence which appears in the tube must not be mistaken for the Roentgen rays.

The Roentgen rays are themselves *invisible*, and are appreciable to the senses only by their effect upon cer-

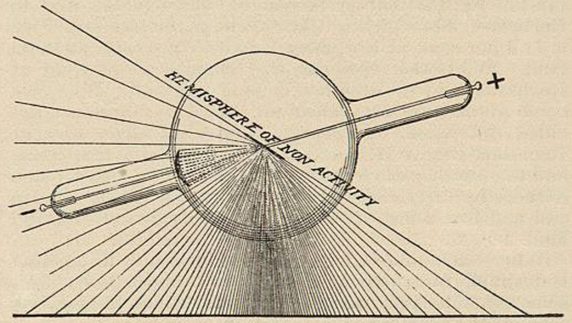

Fig. 4114.—Diagram of Roentgen-Ray Tube with Lines of Roentgen Radiation. The lines diverging from the anode show by their relative proximity to each other those parts of the hemisphere in front of the anode which are more or less acted on by the Roentgen rays.

tain substances. This effect is manifested in three ways: (*a*) by the fluorescence of certain chemical substances when the rays fall on them; (*b*) by the reduction, when exposed to the rays, of certain silver salts ordinarily used for photography; and (*c*) by changes produced in living tissues when the rays act upon them for a sufficient length of time.

The first of these effects, *i.e.*, the fluorescence of certain chemical substances, is the means used for producing visual effects directly from the vacuum tube. When the Roentgen rays fall upon certain substances, notably calcium tungstate, the double cyanide of platinum and ba-

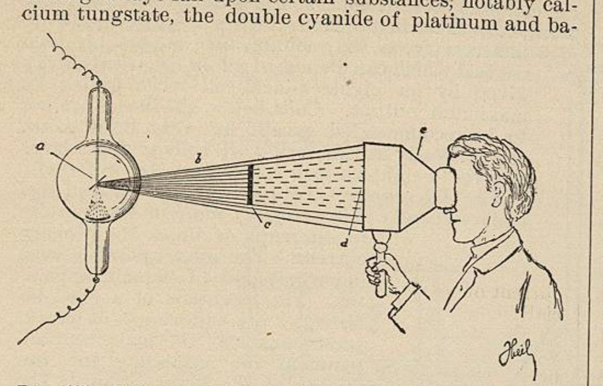

Fig. 4115.—Diagram showing the Fluoroscopic Method of Obtaining Visual Images by Roentgen Radiation. *a*, Anode; *b*, Roentgen rays passing to light-excluding chamber with fluorescent screen *d*, on which appears the fluorescing image formed by rays passing by or through the object *c*.

rium, platinum and magnesium, platinum and potassium, zinc oxide, etc., these substances glow with visible fluorescent light, the fluorescence in a degree depending upon the number and strength of the impinging rays.

This property of producing visible fluorescence is utilized to give visual effects from the rays. A chemical substance which will fluoresce, usually the double cyanide of potassium and barium, is spread and fixed on some plane surface which is opaque to light. Upon excluding light and allowing the Roentgen rays to pass through the support and fall upon the coated surface, this is seen to glow to a degree depending upon the amount of radiant energy which falls upon it. The amount of energy affecting the fluorescent surface depends upon the energy given out by the tube, the distance of the tube from the plate (the effect varying inversely as the square of the distance), and the extent to which the passage of the Roentgen rays to the fluorescent surface is obstructed by objects placed between the sensitive surface and the tube (Fig. 4115).

The visible images produced by the Roentgen rays are in every sense shadow pictures. The objects outlined by the rays are not themselves seen, but only their shadows cast upon a fluorescent screen or impressed on a photographic plate. It is of the greatest importance in interpreting these shadow images to recognize the fact that they are shadows and not real images of the objects observed.

Roentgen rays are always projected in straight lines from the fluorescing anode, and unlike light rays they are incapable of refraction, dispersion, or regular reflection. Consequently the shadow images formed are similar to shadow images made by ordinary light when projected from a point, and therefore depend for shape and size not only upon the shape and size of the object projecting the shadow, but upon the position in which the object is placed, its relative distance from the source of the rays, and the plane upon which the shadow is cast. These facts are of the utmost importance in judging the radiographic image, and a competent observer in reaching a conclusion always considers all these factors and their relation to each other. Correct estimation of the relative value of these factors is of especial importance in ascertaining the size and position of foreign bodies lodged in the tissues, and is to be particularly considered in medico-legal cases where deformity may be inferred from malposition of tube or plate, or from erroneous reading of the shadow picture.

In addition to their non-deviation from the direct lines in which they are projected, Roentgen rays differ from light in that they are capable of passing through or penetrating all substances. This transparency (to use the term) to Roentgen radiation is not, however, the same with all substances, but appears to be in large measure in inverse ratio to the density of the substances. The property of obstructing the passage of the rays differs markedly with different tissues, both normal and abnormal, of the human body; and as the rays which pass through the least resistant tissues are thus able to exert their greatest effect upon the fluorescent screen or photographic plate, the shadow image gives the outlines of certain tissues, and by difference in density it may furnish evidence of normal and abnormal conditions. Thus, for instance, not only are the outlines of a long bone clearly marked out by the rays, but the medullary cavity is shown as well; and, while in radiographs of the normal lung the denser bronchi only are shown, in pulmonary tuberculosis the tuberculous thickenings from their greater resistance to the rays appear as clearly defined shadows.

As to the real nature of the Roentgen rays many hypotheses have been advanced, some physicists holding that they are longitudinal vibrations of the luminiferous ether, others that they are minute particles of matter driven out from the cathode, and others that they differ from ordinary light rays only in the number of vibrations. While consideration of these hypotheses is of interest to the physicist, to the physician and surgeon the practical facts are: (*a*) that *Roentgen radiation is a form of energy projected in straight lines from its source;* (*b*) *that the ease of its passage through the human body depends upon the structure and density of the tissues;* (*c*) *that it is capable of producing molecular and chemical changes in certain substances used for making its action visible, such as the fluorescent screen and photographic plate; and* (*d*) *that it can produce tissue changes by affecting the metabolic action of living cells.*

Practically, the selection of apparatus which will best produce these visual, chemical, and physiological effects is a matter of much importance, and as there are many variations in type of apparatus for producing Roentgen radiation, a careful study of the apparatus and the principles upon which they are constructed is necessary before they can be properly understood and judicious selection made.

Roentgen-Ray Apparatus.—There are two types of apparatus commonly employed for producing the electrical current of small volume and high tension necessary to excite the vacuum tube to Roentgen radiation—the static machine and the induction coil.

The Static Machine.—The static machine is the only apparatus in which an electrical current of required strength and tension is directly produced. In this apparatus the electrical current is produced by the machine and carried direct to the tube, the electrical energy given out being derived from the mechanical energy used in driving the machine. Two forms of static machine are most used—the Wimshurst and the Holtz. Of these the Holtz form is most used in America, while the Wimshurst is almost exclusively used in England. The use of static machines for Roentgen-ray work is much more common in the United States than in any other country. In this country much attention has been paid to this form of apparatus, and a type of apparatus considerably modified from the original Holtz has been developed, which is, with certain limitations, quite satisfactory. The machines now most used (Fig. 4116) have from eight to sixteen circular glass plates mounted on an axle. These plates rotate in one direction, and between them are fixed inductor plates of glass.

The special *advantages* of the static machine are that it is easy to operate, that with ordinary care it is not liable to get out of order, and that it is capable of producing a steady and fairly powerful output, which is not injurious to vacuum tubes. For good work it is necessary to have a static machine of large size, twelve to sixteen plates, thirty-two inches in diameter, or even larger, and it should be driven not by hand but by power, a one-half horse-power motor with speed regulation being required to give good results. The *disadvantages* of the machine are that it occupies much space, that it is liable (unless carefully managed) to fail in damp weather, and that as powerful effects cannot be obtained with it as with the larger coil apparatus. Under proper management a

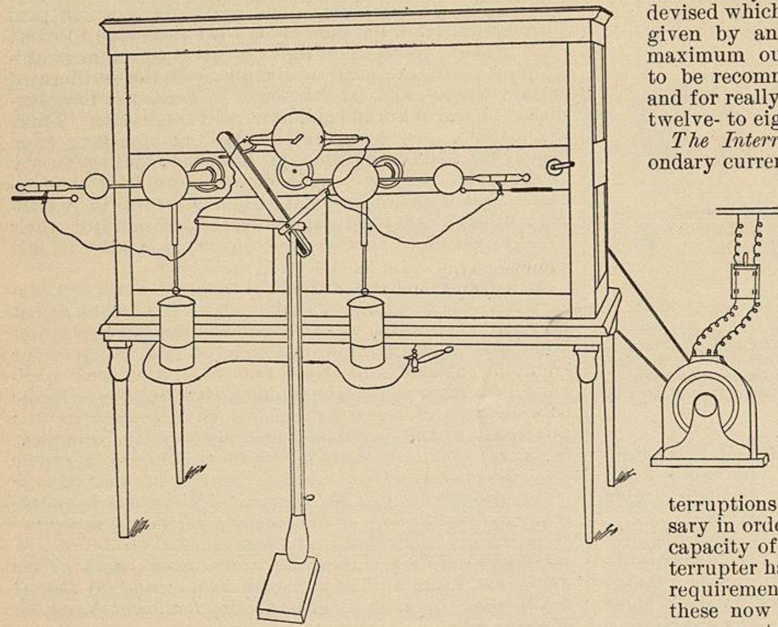

FIG. 4116.—Static Machine Arranged for *x*-Ray Work.

large static machine will do satisfactory fluoroscopic and photographic work, but where therapeutic work has to be done the majority of operators consider a coil apparatus indispensable. With a static machine great care must be taken to keep its interior free from moisture; a tight case and the occasional use of calcium chloride for drying being necessary. In operating it, steady and sufficiently rapid revolution of the plates and careful attention to the use of the "spark gaps" and Leyden jars is indispensable to success. The static machine is to be particularly recommended where commercial electrical currents for running a coil cannot be had, as under these conditions a large static machine run by a water, steam, or gasoline engine will give much better satisfaction than a coil apparatus energized by a primary battery.

Coil Apparatus.—The principal parts of a coil apparatus are the induction (Ruhmkorff) coil, the interrupter, the vacuum tube, and a suitable electrical source. In the coil apparatus, the secondary current of small volume and high tension necessary to excite the vacuum tube is obtained by induction from a primary current of large volume and relatively low tension. The primary current is obtained from primary batteries, storage batteries, or dynamos—when from the latter, the dynamo current for electric lighting is usually employed—and is carried to the coil by insulated wires. In the coil (Fig. 4117) the primary current traverses that part of the coil which is called the primary and, being interrupted with high frequency by the interruptor, by induction produces a current of high potential in the secondary part of the coil, from which it is carried by insulated wires to the vacuum tube.

The Induction Coil.—Induction coils are made of various sizes and are wound to correspond to the primary current by which they are supplied, whether from battery or from dynamo. They should be used only with the current for which they are designed. Their size is given in inches, this indicating the length of spark they give when supplied with a proper current. The longer the spark length, the greater the care which must be employed in manufacturing the coil (to prevent its being destroyed by the powerful currents which are necessary to energize it) and the more the resulting work which the coil is capable of doing. For practical Roentgen-ray work, coils exceeding eighteen inches in spark length are unnecessary, as the vacuum tube has not yet been devised which can dispose of all the electrical energy given by an eighteen-inch coil when giving its maximum output. Coils below six inches are not to be recommended except for very light work, and for really satisfactory work coils giving a large twelve- to eighteen-inch spark are to be preferred.

The Interrupter.—To produce the required secondary current it is necessary more or less rapidly to interrupt or break the primary current. The interrupter is a most important part of the coil apparatus. The essentials of a good interrupter are suddenness of break, good contact at the make, and adjustment for regulating the frequency of the interruptions. The greater the abruptness with which the current is cut and the more instantaneous and perfect the contact when the current is made, the greater will be the effect on the secondary coil; also adjustment for regulating the frequency of the interruptions and the length of the make is necessary in order to adjust the induced current to the capacity of the tube in use. Many forms of interrupter have been devised in order to meet these requirements. There are three main types of these now used—the vibrating spring type, the mercury type, and the electrolytic type. Of these different types the vibrating spring interrupter (Neff's hammer) is the original and simplest form (Fig. 4117).

An upright spring, carrying a heavy piece of iron at its upper end, is fixed on the baseboard so that the iron head is opposite one end of the core of the coil. On the face of the hammer furthest from the core is fixed a piece of platinum, and opposite this is another piece of platinum fixed in the end of a screw held in a brass pillar. The electrical current is carried from one pole of the battery through the coils of the primary to the vibrating hammer, thence, when the platinum points are in contact, to the screw and from it to other pole of the battery. The current magnetizes the soft-iron core, which attracts and pulls the hammer toward it and away from the

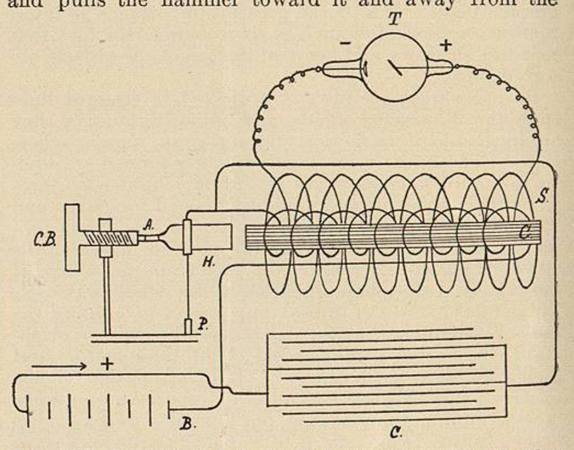

FIG. 4117.—Diagram of Induction-Coil Apparatus with Vibrating Hammer Interrupter. *A*, Contact; *B*, battery; *S*, secondary; *C*, soft-iron core; *H*, hammer; *c*, condenser; *T*, tube.

screw. This breaks the current, the core is demagnetized, and the spring carries the hammer back against the screw, which again completes the circuit, and the process is repeated. By adjusting the screw and the

tension of the spring, the rate of the vibrations and the relative length of break and contact can be regulated to a certain degree to correspond with the tube used.

The advantage of this interrupter is its simplicity, but it is not adapted to coils giving a spark over six inches

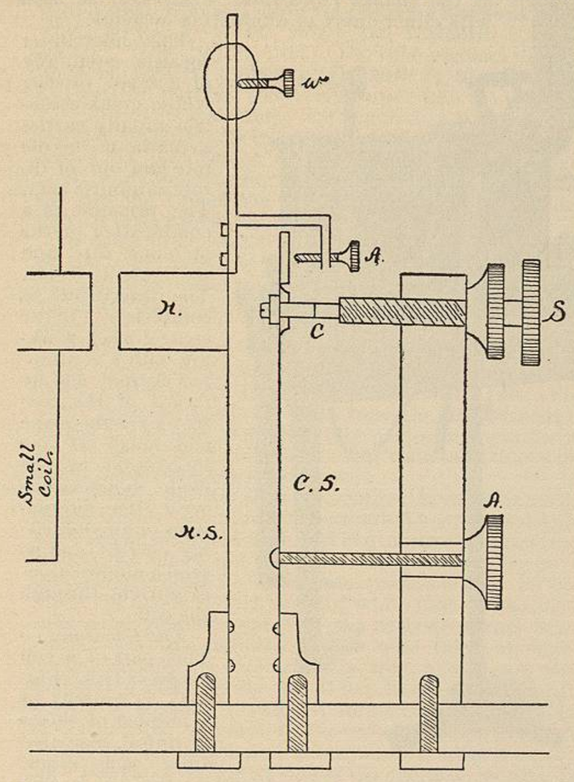

FIG. 4118.—Diagram of Independent Vibrator. *h*, Hammer; *w*, movable weight; *h. s.*, hammer spring; *c*, contact points; *c. s.*, contact spring; *A*, *S*, *A*, adjusting screws.

in length. The break made by it from its occurring when the hammer starts to move, is not abrupt, and the contact from the wearing of the platinum is apt to be imperfect. Also the intense heat developed at the point of contact sometimes welds the platinum points together and stops the working of the apparatus. Large coils, requiring heavy currents, cannot be used with the interrupter, both from the liability of welding the platinum and from the jumping of the current across the gap at the break.

The *independent vibrating interrupter* (Fig. 4118) is a modification of, and a great improvement on, the Neff hammer. With it coils up to fifteen inches, energized by commercial currents up to one hundred and ten volts, can be quite satisfactorily worked. In this form the interrupter is operated by a secondary battery connected by a shunt from the main circuit, and is entirely independent of the main coil.

In this interrupter the current passes from the battery to the coil and returns (Fig. 4118) through *c.s.*, *c.* and *S.*, unless broken at *c*. The current is broken at *c*, by the screw *a* striking the contact spring, when the hammer is attracted by the core of the small coil. This interrupter gives a relatively long contact, and the break is very sudden as the contact spring is struck when the hammer is moving at high speed. The rapidity of the interruptions can be varied in wide range by raising or lowering the movable weight (*w*) on the hammer spring. The advantages of this form of interrupter are that it is easy to manipulate, that it does not readily get out of order, and that it gives good results on all but the largest coils.

Mercury Interrupters.—The mercury interrupters are of two types—the dip interrupters and the turbine. The dip interrupter (Fig. 4119) consists of a small electric motor which, when in motion, rapidly dips one or two silver needles, hung on an eccentric of the shaft, into mercury, overlaid with petroleum, contained in glass receptacles.

The needles being connected with one pole of the battery and the mercury with the other, the current is made and broken by the entrance and exit of the needles from the mercury, while the number of interruptions is regulated by the speed of the motor, and the relation of make to break is determined by the time the needles remain in or out of the mercury.

The *turbine interrupters* (Fig. 4120) consist essentially of a hollow metal cylinder in which openings are cut, and within which a rapidly revolving turbine wheel, by centrifugal force, throws outward a stream of mercury. The cylinder being connected with one pole of the current and the wheel and mercury with the other, the current is made when the stream of mercury impinges against the wall of the cylinder and is broken when it passes through the openings. The rapidity of the interruptions can be regulated by the speed of the motor which runs the turbine wheel, the length of the make and break, by the size of the openings in the cylinder and the distance between them. In practice, the openings are triangular sectors, and the relation of make to break can be varied by raising or lowering the cylinder. The break, from the force with which the mercury is thrown, is extremely sudden. The mercury is used dry, and requires only occasional cleaning.

The dip and turbine interrupters give the highest attainable results. They can be used on the largest coils and with direct currents up to two hundred and fifty volts. The turbine are in many respects better than the dip interrupters, as they are easier to manage and, in the best forms, are capable of more varied adjustment. They are expensive, compared with other interrupters, but for critical and professional Roentgen-ray work are unexcelled.

Electrolytic Interrupters.—These interrupters are entirely different in principle from those above described. Their action

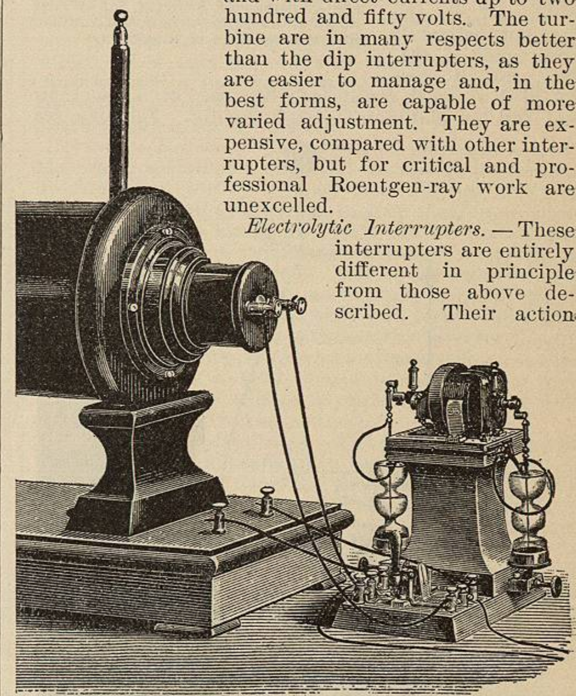

FIG. 4119.—Coil with Mercury Dip Interrupter.

depends upon the electrolytic action of an electrical current. These interrupters consist essentially of a large sheet of lead connected with the negative pole of an electrical current and a small surface of platinum connected to the positive pole, both being immersed in dilute sulphuric acid (Fig. 4121). When a current is passed, electrolytic action occurs in the fluid and the sudden formation and disappearance of a non-conducting envelope of gas about the exposed platinum alternately breaks and makes the currents. In practice, at least forty volts at the terminals of the interrupter must be used to give good results.

These interrupters, from the rapidity of the interruptions, give a steady and intense light for fluoroscopic purposes, but for photographic work the radiation is not so energetic as that given by the mercury interrupters. The advantages of this interrupter are its cheapness and simplicity. Its disadvantages are that it is not fully controllable, that it is liable to explode, and that it is not possible to work it long at a time, as the fluid soon becomes overheated.

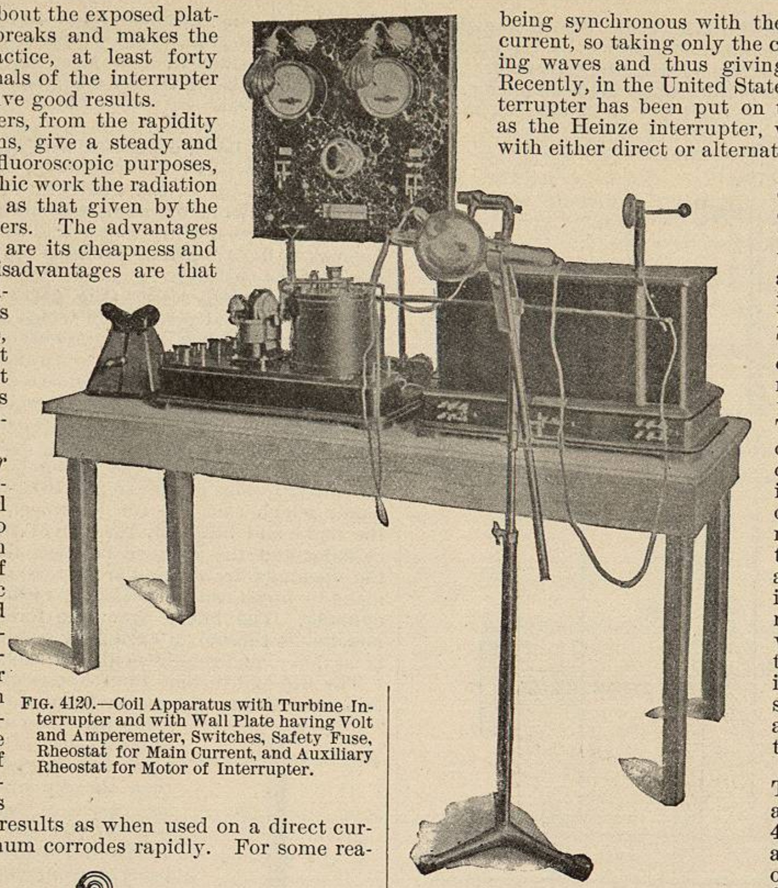

FIG. 4120.—Coil Apparatus with Turbine Interrupter and with Wall Plate having Volt and Amperemeter, Switches, Safety Fuse, Rheostat for Main Current, and Auxiliary Rheostat for Motor of Interrupter.

Interrupters for Use with Alternating Currents.—All the interrupters so far discussed, with the exception of the electrolytic type, can be used only on *direct* currents. The electrolytic interrupter can be used on an alternating current, and is the cheapest method of using such a current; but it does not give as good results as when used on a direct current and the platinum corrodes rapidly. For some rea-

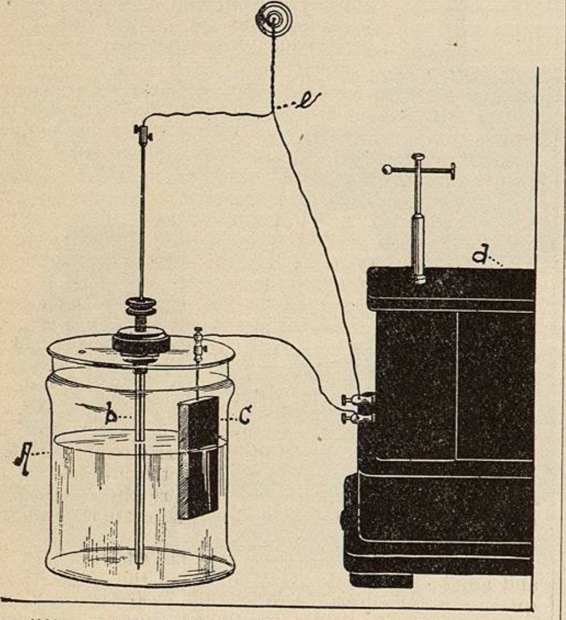

FIG. 4121.—Electrolytic (Wehnelt) Interrupter. *A*, Interrupter; *b*, platinum wire in porcelain cylinder; *c*, lead plate; *d*, coil; *e*, wires connecting interrupter and coil with an electrical source.

son the electrolytic interrupter does not explode or "choke" (cease working) on alternating currents.

Synchronous interrupters of the turbine mercury type are considerably used abroad for utilizing alternating currents. They depend in principle upon the make being synchronous with the alternation of the current, so taking only the crest of the alternating waves and thus giving a direct current. Recently, in the United States, a form of dip interrupter has been put on the market, known as the Heinze interrupter, which can be used with either direct or alternating currents.

This interrupter consists essentially of a small motor whose crank eccentric rapidly carries a platinum needle into and out of dilute sulphuric acid. The principle is a combination of the mercury dip and the electrolytic. The interrupter is completely under control when working with a continuous current, and by means of the control lever the make and break of the interrupter can be made synchronous with the alternations of an alternating current, and so send a unidirectional current through the coil.

The Condenser.—This part of a coil apparatus (Fig. 4117, *c*) consists of a number of sheets of tinfoil, insulated from each other, and connected with the wires by which the coil is connected with the electrical source. The function of the condenser is to act as a sponge and, when the interrupter breaks the current, instantly to absorb the electricity in the primary and so completely and immediately to demagnetize the core, thus greatly increasing the energy in the secondary. So energetic is this action that a twelve-inch coil without a condenser will barely give a two-inch spark. The condenser is usually placed in the base of the coil, but may be mounted separately. With the electrolytic interrupter no condenser is used.

Vacuum Tubes.—Tubes are graded from low (soft) to high (hard). A high or hard tube is one of high vacuum. These tubes require powerful currents to excite them, and they produce rays of great intensity. With such tubes the shadows of the bones viewed with a fluoroscope appear gray, and metallic objects are readily seen through them. Tubes of this character are very energetic in action on the photographic plate, and are useful for work through thick parts, as the hip, pelvis, or head.

A low or soft tube is one of low vacuum. Low tubes are readily illuminated by currents of low power, and therefore give rays of low intensity and penetration. Between the low and high tubes there are all gradations. Low tubes have too little penetration for work with any but extremely thin parts of the body, while very high tubes give such powerful rays that sufficient contrast between the bones and surrounding tissues is lost and critical differentiation of structure is impossible. Moderately high tubes are best for general work both in radiography and in therapy.

In using a vacuum tube it is necessary to adapt the current to the tube or the tube to the current, or both to each other. The current is regulated in the static machine by the rapidity of revolution of the plates and by adjustment of the spark gaps. In the coil apparatus the

strength of the primary current is regulated by a rheostat, and the quality of the secondary current is conformed to the tube by adjustment of the interrupter. With respect to conforming the tube to the current, tubes are divided into non-regulating and regulating tubes.

Regulating tubes consist of the usual vacuum tube with a small attached bulb containing a chemical which when heated gives off vapor and reabsorbs it when cooled. When the vacuum of the tube becomes too high it can be lowered by heating the bulb by the passage of an electrical current, so forcing vapor into the tube. A very ingenious and useful self-regulating tube has been devised by Queen (Fig. 4122). In this the chemical is heated by the current passing to an adjustable spark point, and by adjusting the distance of this point from the cathode connection any desired degree of vacuum may be maintained.

In tubes to be used with the powerful currents given by the larger coils and rapid interrupters, special provision has to be made to prevent rapid destruction of the anode by the powerful cathode stream which impinges upon it.

Where the current is moderately powerful, tubes with extra thick anti-cathodes will resist the cathode stream. With powerful apparatus the water-cooled tube (Fig. 4123) must be used. In this tube the anti-cathode is placed at the base of an inwardly projecting cylinder, so that it can be kept cool by running water and thus withstand the great energy developed.

Success in the use of the Roentgen ray-apparatus depends largely upon proper manipulation of the tube and the current supplied to it. When a tube is used, care should be taken not to allow the platinum anode to become overheated. As a rule, radiation is at its best when the anode is just short of white heat at its centre, where the greatest energy of the cathode stream is exerted. For this radiation, tubes with thick or water-cooled anodes are required, as thin anodes are soon perforated and destroyed. When in operation the tube should be constantly watched, for on account of the heat developed the vacuum in the tube becomes gradually lower, and as the current passes more readily the anode may become overheated unless the operator reduces the current. Tubes become higher with use. When a tube refuses to illuminate, careful application of heat will overcome its resistance for a time; but, with use, it will finally become so hard that no current can pass through it. When this occurs, re-exhaustion is the only remedy.

ELECTRICAL SOURCES.—Three sources of electrical current are used for Roentgen-ray purposes—dynamos, storage batteries, and primary batteries.

The *dynamo currents* generally used are from commercial electric-light circuits, and this kind of current is best

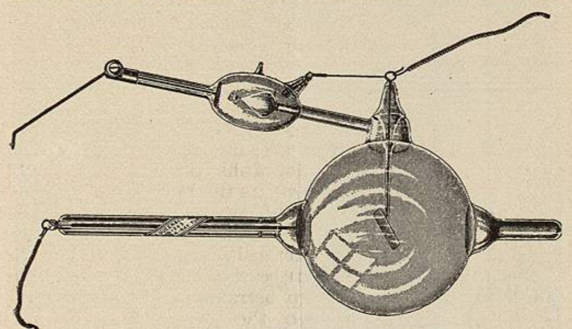

FIG. 4122.—Queen Self-Regulating *x*-Ray Tube.

for Roentgen-ray work, where it can be had, as it affords sufficient energy to operate the coil and the discharge may be made as heavy as desired. Commercial currents are either continuous or alternating. The *continuous current*, unless of very high voltage, can be carried direct to the coil, requiring only a rheostat for regulating it and a safety fuse to prevent accidents. These currents are usually one hundred and ten volts, and all forms of interrupter can be used with them. Currents of higher voltage may be used, but with two hundred and twenty volts, or higher, the "reactive kick" of the primary becomes so great as to be a source of danger to the oper-

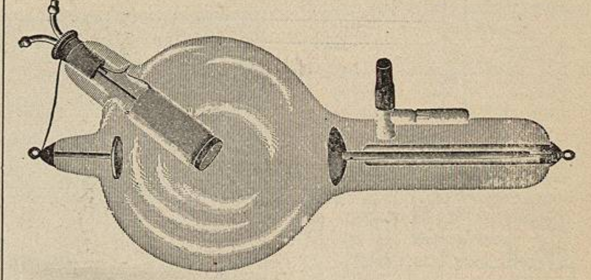

FIG. 4123.—Water-Cooled Tube.

ator in case of accidental contact with certain parts of the apparatus. With these high-volt currents it is best to use a current transformer which reduces the current to a point of safety.

The *alternating current* can be used only with an electrolytic interrupter, a Heinze interrupter, or a synchronous mercury interrupter.

Storage Batteries.—Next to a dynamo current that from a storage battery gives best satisfaction. Storage batteries, like batteries generally, have the disadvantage of being more or less difficult to keep in order. The "chloride accumulator" is probably the best type and, in its more compact form, is useful for making part of portable apparatus. These batteries can be charged from dynamo currents or from primary batteries. To charge from an alternating current, a current rectifier, which takes only the crests of the alternating waves, must be used. To give a good output, a little more than one cell of a battery is required for each two inches of spark length given by the coil.

Primary Batteries.—This form of electrical source is the least desirable of any used for energizing coils for Roentgen-ray work. Primary batteries are bulky, require a great deal of attention to keep them in order, and are expensive to maintain. They can be recommended for use only where commercial circuits or storage batteries cannot be employed. Any of the more energetic forms of battery will run a coil, but, from the trouble incident to working them, only one form—the Edison-LeLande battery—can be satisfactorily used for this purpose. This battery requires comparatively little attention, and gives a very constant electromotive force. About four battery cells are required for every two inches of spark length given by the coil.

Installation of Apparatus.—The method of assembling a coil apparatus depends upon the current supplied, the form of interrupter used, and the size of the coil. With a small apparatus having a hammer interrupter and energized by a primary or storage battery, it is only necessary to connect the coil direct to the battery. When a continuous commercial current is used a safety fuse and rheostat should be placed in the main circuit to protect the coil from injury and to regulate the current. When a mechanical interrupter is used it is run by a shunt from the main circuit, and should have a separate rheostat and safety fuse (Fig. 4124).

In installation of the larger coils the addition of a volt and ampere meter is useful to show the quantity and quality of the current, and wall plates are made having safety fuse, rheostats, and volt and amperemeters conveniently assembled on them (Fig. 4120). With an electrolytic interrupter the installation is somewhat simplified, as the interrupter is placed directly in the circuit which supplies the coil (rheostat and safety fuse being used) and a condenser is not required (Fig. 4125).

SURGICAL USES OF THE ROENTGEN RAYS.—The principal surgical uses to which Roentgen radiation is put are: (*a*) to diagnose fractures and determine the form and extent of the bone lesions; (*b*) to diagnose dislocations; (*c*) to determine the existence and extent of acute, chronic, and neoplastic pathologic changes in the bones;

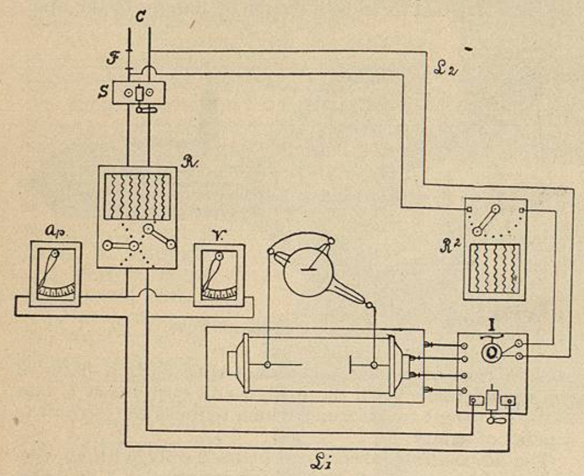

FIG. 4124.—Diagram of Installation of an Apparatus with Mechanical Interrupter. *C*, Wires to maintain circuit; *F*, safety fuse; *S*, switch for connecting current; *R*, rheostat for current to coil; *Ap*, *V*, ampere and volt meters; *Li*, wires to coil; L_2, wires to interrupter; R^2, rheostat for interrupter; *I*, interrupter.

(*d*) to determine bone malformations and deformities; (*e*) to determine the presence and location of foreign bodies.

The peculiar resistance of osseous tissues to the Roentgen rays makes traumatisms of these particularly easy to determine. By the proper use of the rays the presence or absence of fracture, and, if present, the form and extent of the bone trauma can be accurately determined. Cases of difficult diagnosis are made plain, and since the rays have come into use it has been demonstrated that fracture is present in many obscure cases thought to be severe strain or sprain. The attention of the writer has been particularly called to this fact in connection with injuries of the knee-joint. Recently two cases of persistent lameness were referred to him, which were supposedly due to severe strain. In one of these cases the external condyle of the femur was split off to the intercondyloid notch (Fig. 4126) with no displacement, and in the other the internal tuberosity of the tibia was similarly fractured. In both these cases no crepitus could be elicited; the only prominent symptoms were persistent swelling and pain at the joint and the patients walked about with the aid of a cane.

Not only has the use of the rays given the surgeon a sure method of determining the presence of fracture, but it has greatly increased his knowledge of fractures resulting from indirect and direct violence, particularly those forms which are due to gunshot injury. The facts disclosed have been extremely valuable from the standpoint of treatment, for it has been conclusively proven that conservatism is indicated even in cases of most extensive bone lesion, provided the wound is not infected. In fact, as a result of Roentgen-ray observations combined with clinical experience, the rule may now be formulated that whatever the extent or form of a fracture, if no infection is present, operation is contraindicated, unless the bone fragments are so displaced that they produce deformity, may interfere with the function of the part, or are pressing upon vital or important structures.

When the diagnosis lies between a suspected fracture and a dislocation, as in obscure injuries of the elbow-joint, the rays at once determine the matter accurately. They are equally effective in showing the result of treatment, and at once enable the surgeon to determine whether or not a dislocation or fracture has been properly reduced (Figs. 4127 and 4128).

In determining the presence and extent of bone lesions it is most important that the rays be properly used. As before stated, visual effects from the rays are from observed shadows, and these shadows depend for shape and size not only upon the shape and size of the objects casting the shadows, but upon the relative position of the light and object and their distance from each other. For these reasons, to reduce distortion to the minimum, radiographs should always be made with the tube so placed that the anode will be as nearly as possible on a line perpendicular to the long axis of the bone above the place of fracture, and at least eighteen inches distant from it. Also, when the part injured admits, radiographs should always be taken from two directions, preferably at right angles to each other. Unless this precaution is taken, a fracture may be overlooked from the fragments overlying each other in a direct line and so throwing a straight continuous shadow, when a radiograph taken at another angle will at once show a displacement.

In this connection the *medico-legal* aspects of radiography may be considered, and here again the fact must be emphasized that radiographs are shadow pictures, not actual pictures of the objects themselves, that consequently the images are *never* accurate representations of the objects, that distortion is always present to greater or less extent, and that proper reading of radiographs can, in difficult cases, be arrived at only after much experience on the part of the expert; and then information must be at his disposal, giving the relative position and distance from each other of the tube, the plate, and the object radiographed. It is also primarily essential to expert opinion that this opinion be based upon full knowledge of radiographic pictures of normal structures, particularly of the shadow images given by the bones at the articulations.

For medico-legal as well as for diagnostic purposes, it is to be noted that *bone callus* is at first quite transparent to Roentgen rays, so much so that a fracture which is quite firmly united may show on the photographic plate as though no callus existed, and so give the appearance of an ununited fracture. For this reason the Roentgen rays cannot in all cases be relied on to give the actual condition of union or non-union of fracture.

The Localization of Foreign Bodies in the Tissues and in the Body Cavities.—The advantages of the Roentgen rays over all other means of locating foreign bodies are now so well understood that their use has practically entirely superseded all other methods.

The difficulties of using the probe for locating lodged missiles is well known. The contractility of tissues

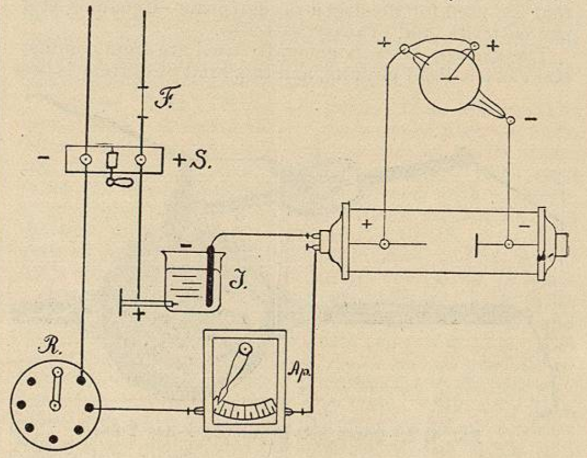

FIG. 4125.—Diagram of Installation of Apparatus with Electrolytic Interrupter. *S*, Switch; *F*, safety fuse; *R*, rheostat; *Ap*, amperemeter; *I*, electrolytic interrupter.

and the shifting of muscular and fascial structures by change of position may completely obstruct the wound track; and after the wound is healed, unless the foreign

body can be felt beneath the skin, its localization by other than the Roentgen rays is usually impossible. With these all parts of the body may be painlessly and safely explored, and the presence or absence of foreign bodies determined, and if found, they may be accurately located. In a great majority of cases the localization of a foreign body in the tissues is a comparatively simple process.

Direct observation with a fluoroscope or a radiographic picture will give all necessary information. In such cases the position of the foreign body relative to surface markings and points on the bones will materially aid in determining its position.

The depth at which a foreign body lies and its position may be determined with absolute accuracy by views taken at different angles. The principle involved is that as the anode, the object, and the shadow of the object are always in line, when two observations are made with the position of the anode changed, it must follow that the object must lie at a point where the lines drawn from the shadow to the anode at each observation cross each other. In other words, if two observations are made with the anode in different positions for each, and these positions and the places where the shadows of the object fall at the surface of the body are marked, the object can be located at the point where lines cross each other, which are drawn from the positions occupied by the anode to the places on the surface of the body where the shadows of the object were cast. Various means have been devised for determining the positions of the anode and the shadows of foreign bodies relatively to the surface of the body. Of these the MacKenzie-Davidson apparatus, or one of its modifications, is most convenient and accurate, and with such apparatus foreign bodies can be located with mathematical exactness.

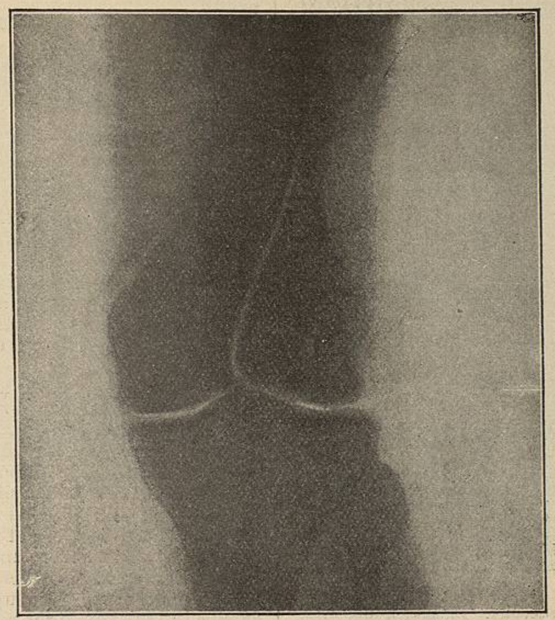

FIG. 4126.—Radiograph showing Fracture of the External Condyle of the Femur.

For locating foreign bodies in the eyeball, Dr. Sweet has invented a very ingenious and satisfactory apparatus.

Calculi.—Recently great advances have been made in determining the presence of pathologic foreign bodies in the urinary and gall bladders and in the kidney.

The pathologic concretions formed in these organs, from their difference in composition and consequent resistance to the Roentgen rays, differ materially in the ease with which they may be detected. Those calculi which contain inorganic material, such as the mineral salts, may be most easily made out. For this reason gall stones are difficult to radiograph, as they are generally composed of organic matter. Uric-acid calculi are quite transparent to the rays and consequently difficult to determine. For these reasons while a radiograph showing a shadow cast by a calculus is proof positive of the presence of a calculus, the absence of a shadow is no indication that a calculus may not be present, as the calculus may be so transparent as to cast no shadow. However, with proper technique, the presence of calculi may be demonstrated, when present, in a large percentage of cases.

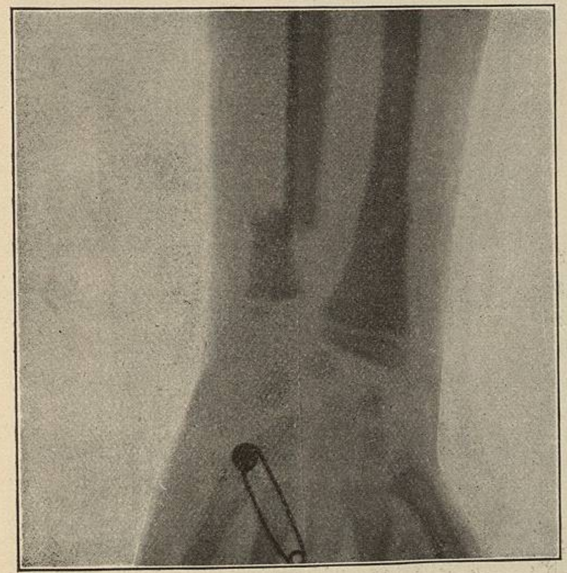

FIG. 4127.

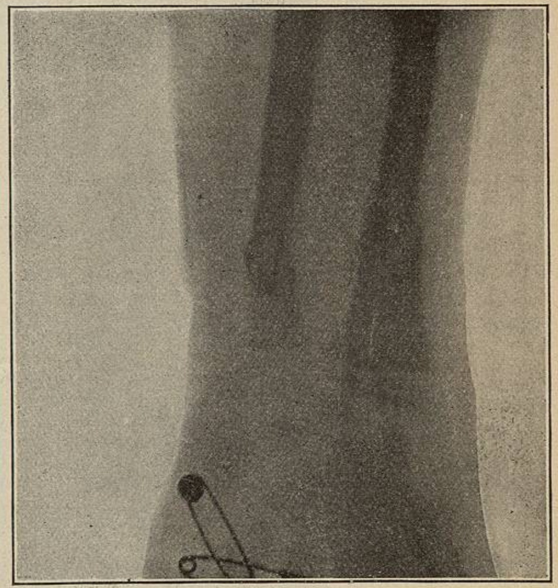

FIG. 4128.

FIGS. 4127 AND 4128.—Radiographs of a Fracture of the Radius and Ulna before Reduction (Fig. 4127), and after Reduction and Wiring (Fig. 4128).