NOTES ON X-LIGHT

WILLIAM ROLLINS

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BY

WILLIAM ROLLINS

BOSTON, MASSACHUSETTS
MCMIV

To

M. W. R. and J. R. R.

PREFACE

In these notes are recorded some impressions derived from experiments made after the day's work, as a recreation, yet with the hope of learning to design and construct apparatus for my friend, Dr. F. H. Williams, who has done most to show the importance of X-light in medical diagnosis.

WILLIAM ROLLINS.

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ERRATA

Page 2. For "tungsdate" read "tungstate."
" 2. Insert "Plate 1" between "end" and "Sc."
" 11. For "shall" read "should."
" 45. For "26" read "36."
" 165. For "173" read "174."
" 170. For "Plate 50, Figure 87," read "Plate 51, Figure 88."
" 170. For "Figure 88" read "Figure 89."
" 203. Omit the apostrophe after "centimetres'."
" 225. For "177" read "179 I."
" 233. Insert "capacity" after "storage."
" 244. Omit "81." Insert "78, 79," before "80." Insert "84" between "83" and "85." Insert "4, 5," between "Figures" and "5½." Insert "8½" between "8" and "9."
" 246. Omit "and B."
" 254. For "115" read "139." For "119" read "140," in the sixth line. For "119," in the twenty-seventh line, read "139."
" 266. For "115" read "116 B."
" 271. For "115" read "116 B."
" 276. For "139" read "140."
" 279. For "137, March 29, 1902," read "117, March 9th, 1901."
" 283. For "108" read "106."
" 283. For "Figure 2" read "Figure 3."
" 287. For "119" read "117."
" 295. Omit "it," in the fourth line of Note 160.
" 298. After "RH 5" insert "Plate 116, Figure 8."
" 303. After "R 2" insert "Plate 120, Figure 8."
" 305. After "H" insert "Plate 117."
" 305. For "139" read "140."
" 306. For "139" read "140."
" 318. For "146" read "166."
" 323. For "149" read "159."
" 363. For "cyanide barium" read "cyanide of barium."

NOTES ON X-LIGHT

NOTE A—ON RENDERING COMMERCIAL ELECTRICAL CURRENTS SAFE FOR THERAPEUTICS

The ordinary way of using the street current in electrotherapeutics is to reduce the current by a compact resistance on one wire. With this arrangement two dangers are present. Turn to any recent work in which resistances are figured and see how near together are the binding posts of the single resistance on the heavily charged street wire, and how easy it would be to expose a patient to a powerful current by cutting out the resistance entirely by an instrument or a wire falling in such a way as to bridge the resistance. Or suppose, as is commonly the case, the street current is the Edison three-wire system and the resistance is on the neutral wire, as it frequently is, for all three wires look alike. Then if any part of the body touches a terminal of one of the numerous circuits required by a physician in therapeutics, or even a gas burner, the patient may get a severe shock. To avoid danger neither a single nor a compact resistance should be used. High up on the wall out of reach should be placed a resistance equally divided between the wires, which even in the event of a short circuit will allow too small a current to pass through the patient to do harm. Between this basic resistance and the patient place a variable resistance also equally divided on the wires and so arranged that one movement reduces the resistance equally on each wire.

International Dental Journal, March, 1896.

NOTE B—A REFLECTING CRYPTOSCOPE AND CRYPTOSCOPIC CAMERA WITH NON-RADIABLE WALLS

Roentgen's discovery that fluorescent substances converted his rays into light rays has been of less value to dentists than to surgeons, for it would stretch even a large mouth to put a Crookes tube or an Edison fluoroscope into it. The small size of the instrument here figured is therefore an advantage, as it allows the vacuum tube to be outside the mouth.

It consists of a metal tube bent at a right angle. The short end -Sc- is closed water and light tight by an aluminum disk three one-thousandths of an inch thick. Beneath is a glass disk -Gd- with the surface next the aluminum coated with Edison's tungsdate of lime. In the angle is a quartz mirror -M-. Over the long end of the tube slides another tube with a flaring end -Ep-, having a rim of soft rubber fitting closely about the eye. In the end is a lens -L-. By sliding the tube the image formed in the mirror is brought to a focus in the eye.

To use the instrument the Crookes tube is held outside the mouth with its radiant point opposite the aluminum disk, which is pressed against the mucous membrane inside. After use, to sterilize the instrument it is only necessary to remove the mirror and coated glass, when the other parts, which alone come in contact with the tissues, can be baked without injury. The short end -Se- unscrews to allow of the use of other forms. The second here figured is used in examining for stone in the bladder. To photograph with the instrument the film is cut into disks with a punch and placed under the aluminum, with a second disk behind it to prevent the light entering the long end from reaching it.

When the instrument is to be used as a camera alone, the films should be arranged in the following way: Place one film with its coated surface next the aluminum disk, back of this a sheet of aluminum, then a film, repeating this until twelve are in the camera. The object is to give the films varying amounts of exposure. This is a new principle in Roentgen photography which, when applied to other parts of the body, will bring out structure that cannot be got in any other way. In working on a larger scale and with glass plates the aluminum dividing plates can be omitted, as the glass itself is somewhat opaque to the rays.[1]

International Dental Journal, July, 1896.

NOTE C—AN ORAL CAMERA FOR X-LIGHT PHOTOGRAPHY

Until some better converter is found for X-light, the visual examination of the teeth will give less perfect results than the photographic. A dentist will therefore need, in addition to the cryptoscopic camera shown in the July number, a separate camera, because where the instrument

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[1] Note added 1903.—Multiple X-light photography was invented by E. Thomson. The use of a somewhat opaque substance between the films is all that has proved to be original in the plan mentioned. Refer to Note 54.

is used only for photography it may be smaller and cause less inconvenience to the patient. Plate 2, Figure 1, shows such a camera full size. It consists of a hollow metal handle, MH, a flexible sliding brass rod, BS, held in any position by the set screw, SC, and supporting the camera-cell, CC. Bending the brass stem allows the camera to be placed in several positions. When this stem breaks from frequent bending, a new one can be inserted in a moment, the thread in the steel boss cutting a thread on the brass as it is turned in. Plate 2, Figure 3, shows the camera in pieces. RR is a soft rubber ring, clasping the collar BC when in position, as shown in Plate 2, Figure 1, thereby preventing painful pressure on the mucous membrane. AD is an aluminum disk, which, when the brass collar BC is screwed on CC, closes the camera light and water tight.

The instrument is to be used like the one described in the July number. A very simple form of camera can be made in the following way: Cut the sensitive films from kodak tissue, making them seven-eighths of an inch wide and an inch and a quarter long. Arrange them, after rounding the corners, like the leaves of a book, and slip into a little envelope of black paper enclosing them in a rubber cot, closing the end by folding over and securing with a bent steel wire. This sort of camera is very flexible, and is easily held against the mucous membrane with the finger.[2] Whatever form of instrument is used, the best results are obtained by getting the sensitive photographic surface as near the point to be photographed as possible, and using that form

[2] The hand should be protected by a non-radiable rubber glove.

of tube in which the light is given off from a small intense source.

The uses to which Roentgen's discovery can be put in dentistry are many. It makes at least one new operation easy. Where a temporary tooth had remained for several years after it should have been shed, doubt was felt about the best course to take when it was a front tooth, because it was impossible to tell whether there was a second tooth under it. Roentgen photography solves this problem: we can remove the first tooth and open the socket of the second to allow it to erupt.

International Dental Journal, August, 1896.

NOTE 1—A COOLED TARGET X-LIGHT TUBE

As the X-light tube described in the Electrical Review for November 24, 1897, has attracted some attention, it will be described in detail. The tube is of the so-called focus type, in which the cathode rays impinge on a platinum anode, the surface of which is placed at an angle of 45 degrees with the long axis of the tube. To admit of the use of a long spark, the distance between the external terminals is much greater than in the present tubes. If a spark of 15 inches in air is used, the distance between the terminals should be 20 inches, and about this proportion should be maintained in using longer sparks. The centre of the anode surface should be in the focus of the cathode at the degree of vacuum at which the tube is sealed. This has before been impossible, as the anode would quickly be destroyed by heat, even with the moderate currents now used. The anode has always been placed incorrectly in relation to the cone of the cathode rays, resulting in a large radiant point, making the best definition impossible. For financial reasons the anode is short, the necessary length of the tube between the terminals being obtained by extending the cathode stem. The hollow platinum anode, sealed in, has a tube inside, as shown in the diagram.

One end of this tube is connected with a reservoir of water, and the supply, regulated by a stopcock, is maintained of sufficient volume to keep the water dripping from the outlet tube cool to the finger when the tube is excited by the full capacity of the generator. A small flexible rubber tube attached to the outlet removes the waste water. If air is used, the inlet pipe is attached to one end of a rubber tube, the other being connected with a small air compressor operated by the motor of the generator.[3]

The inner tube is not permanently united with the anode, the joint being a bit of rubber tube; it may therefore be made of cheap metal.

The objection to this tube is its first cost, due to the amount of platinum. As the same anode can be used again, this objection is not very serious. Moreover, a modification of the same principle which is cheaper to construct will be mentioned later.[4] — Electrical Review, December 1, 1897.

NOTE 2 — THE RELATION OF THE CATHODE RAYS TO THE SURFACE OF THE CATHODE

Crookes said molecules were given off from the cathode at right angles with the surface. Though this is the accepted theory, the following is proposed: The angle of the lines of force

[3] Refer to Note 37. [4] Refer to Note 11.

with the surface of the cathode depends upon the degree of the vacuum.[5] This deduction is based upon experiments and Frei's experience in making X-light tubes.

To go slightly into detail, we will suppose the cathode is concave, as shown in one of Crookes' figures, and has the curvature of a sphere of two inches diameter. The focus will be one inch, but as the vacuum rises the cone of rays grows longer, while at a vacuum about right for good X-light effects with ordinary apparatus, the point will be two inches from the cathode, and no anode will bear the fierce bombardment from any considerable current, unless kept cool, as is done in the tube, described in the Electrical Review for December 1, 1897.

Electrical Review, December 15, 1897.

NOTE 3—THE FORM OF THE CATHODE STREAM

If it should be accepted that with a concave cathode the focus of the stream varied in distance from the surface, then the following suggestion might be of interest:

If the stream is formed because the molecules[6] having the same charge as the cathode are repelled by it, they ought also, having the same

[5] Note added 1903.—This note is not clear. The courses of many cathode stream sub-atoms are curves. —Note 3. The straight line mentioned is supposed to be drawn from the point where the sub-atom leaves the cathode to that where it strikes the target. This line is not perpendicular to the surface of the cathode except in the case of the central sub-atoms.

[6] Note added 1903.—When the word molecule is used in connection with the cathode stream, substitute the word particle.

charge, to repel each other. If the cathode is circular and its surface a plane, the molecules leaving this perpendicular to its surface and moving in straight lines should form a cylinder, if they did not mutually repel each other. If they repel each other, the cylinder should widen out. If the surface of the cathode is concave with a spherical curvature, they should come to a focus at the centre of curvature if not influenced by mutual repulsion. If they tend to repel each other they should come to a focus beyond this. If the vacuum increases, the potential required to drive the stream rises. This will be accompanied by a stronger repulsion among the molecules and between them and the cathode as well as by a diminished lateral effect from the molecules of the residual gas. As a result the focus should be farther away from the surface of the cathode.

Electrical Review, December 8, 1897.

NOTE 4—MOVABLE TERMINALS AND TARGETS IN VACUUM TUBES

Where the amount of force sent through a focus tube is not enough to injure the anode by heat we can make either terminal movable. Or both being fixed in the usual way we may make the tube cylindrical and have a movable target of suitable material between the terminals on which to receive the cathode discharge.[7] By mounting this in an iron shoe we can readily adjust it to the proper distance from the cathode by a magnet applied to the outside of the tube. When we use more force in a tube it is neces-

[7] Note added 1903. — Consult Notes 16 and 31 in regard to this position of the target.

sary to have the anode fixed in order to cool it, as shown in the note in the Electrical Review for December 1, 1897. In this case the anode becomes a fixed target. The cathode corresponding to a rapid-firing gun is made movable, to adjust it to the proper range, depending upon the vacuum and the potential. A tube of this kind is shown in Plate 4, Figure 4. The figure is somewhat diagrammatic, for no sealing point or cooling arrangements are shown. The tube is supposed to be attached to the pump in order to adjust the vacuum to suit the experiment. It will not bear transportation because the glass would be broken by the weight of the cathode, which consists of a ring of soft iron with an aluminum mirror burnished in and connected with the terminal by a platinum wire too fine to move it out of position. When we desire to use such a tube sealed from the pump we should attach a potash tube, thoroughly boiled out, to admit of lowering or raising the vacuum quickly. We should make the concave aluminum cathode with a stem eight inches long and one-tenth of an inch in diameter, causing it to slide easily in an aluminum tube which will take the place of the ordinary stem. By means of graduations on the stem its distance from the target is easily read. In this form it is practical for use in medical diagnosis, where we wish to quickly adjust for the best definition.— Electrical Review, December 15, 1897.

NOTE 5—ONE CAUSE FOR THE RISE IN VACUUM OF X-LIGHT TUBES OF THE FOCUS TYPE

Every one who has had experience knows the ordinary type of focus tube grows dark in use and the vacuum rises. These results are directly proportional to the force sent through the tube. In using a tube having a hollow platinum anode cooled by air or water, the same amount of force can be expended in the tube without producing these results. Though platinum forms compounds with oxygen, it is not probable the rise in vacuum is due to this, for if we exhaust the tube to a high vacuum, admit nitrogen and again exhaust, repeatedly, the chances are there will be less oxygen in the tube, and yet equal force acting in the same time produces equal blackening and raising of the vacuum. It is therefore probable one cause of the rise is that particles of platinum torn off from the anode and straining through the ether strike molecules of the residual gas, and drive them against the glass, holding them there. As these particles of platinum are probably much larger than molecules, it is easy to imagine this could take place.[8]

Electrical Review, December 15, 1897.

NOTE 6 — THE X-LIGHT WAVE-LENGTH DEPENDS UPON THE POTENTIAL

When we try to see what goes on in a vacuum tube, looking at it "with that inward eye which is the bliss of solitude," the X-light appears to differ only in degree and to be dependent for its penetrating power upon the potential of the current and the degree of the vacuum in which the cathode discharge takes place. We should bear these probabilities in mind in the practical application of the light to medical diagnosis, arrang-

[8] Note added 1903. — An uncooled target may become red-hot, and on cooling absorb gas, raising the vacuum. The particles torn off from the target have a high temperature. On cooling they absorb gas.

ing the potential to make rays of the proper length for our purpose. If we wish to see the outlines of the bones of the hand distinctly we shall keep the potential low, to make the contrast with the soft tissues great, while if the bones are more deeply seated we should not use a tube with a higher vacuum to send the light through a greater thickness of tissue, but we should keep the potential and vacuum the same to prevent altering the wave-length, and increase the light by making more impacts upon the target from the cathode discharge.

Suppose we take a tube with the lowest vacuum in which we can generate any considerable amount of X-light. In this tube the anode must be cooled and the cathode movable. The tube should have a potash bulb, as used by Crookes, to quickly lower the vacuum or raise it again. The curvature of the concave cathode is to be that of a sphere of two inches in diameter. A spherical curvature is not the best; but as Kipling says, "that is another story." With a very low vacuum we can generate X-light with the anode nearly in the centre of curvature, or a little over one inch from the cathode, and yet have good definition if we have taken care in grinding the concave surface. If we look through a hand, the bones seem very dark because of the contrast with the softer tissues. If, with the same potential, we increase the number of impacts upon the anode-target from the cathode discharge, we make both bones and soft tissues lighter without much changing the relative values. If we raise the potential and the vacuum, focussing the cathode stream on the target again, we shall find, as previously stated in these notes, the distance between the cathode and anode is increased, while the bones are, relatively, more transparent. Every time we do this with higher potentials and vacuums, the relative opacities of two substances are changed; and we could go on building more powerful apparatus until we could make rays to which all the so-called elements would be as transparent as glass to light. Platinum being then permeable, we could, for some of our work, abandon internal cooled reflecting anodes and use a form of tube employed in some of these experiments; the platinum, in the form of a disk, being sealed into the wall of the tube, corresponding somewhat to Lenard's aluminum window. Then, by using higher potentials and cooling both terminals, we could produce very short vibrations.

Electrical Review, December 22, 1897.

NOTE 7—OTHER REASONS WHY THE VACUUM OF AN X-LIGHT TUBE GROWS HIGHER BY USE

If we have a tube with two fixed terminals, a movable platinum target, which is not cooled and is placed as nearly as possible at the apex of the cathode discharge, we shall in time raise the vacuum if we send sufficient force through the tube. If we study the appearance of the target, we shall see that molecules of aluminum from the cathode driven against it are so heated as to combine with the oxygen of the residual gases. One way to prevent this is to have only inert gas in the tube, another to cool the target, and there are times when it is best to cool the cathode. Another reason why the vacuum rises has been pointed out by Mr. Kirmayer. Sometimes the glass wrapping of the platinum wire supporting the anode gets cracked. This does no harm until the tube is reversed. Then a spark forms, the vacuum rising rapidly. The cause is not definitely determined, but until further investigation may be considered one of combustion.

Electrical Review, December 29, 1897.

NOTE 8—WHY THE DEFINITION OF A REFLECTING FOCUS X-LIGHT TUBE IS BETTER IN ONE PLANE THAN ANOTHER

If we study the target mentioned, we shall see the roughness caused by the cathode discharge has an oval figure. However perfectly the curvature of the cathode is ground, mechanical and other reasons prevent bringing the discharge to a point. Moreover as the surface of the anode is at an angle of forty-five degrees there must always be part of its surface where some of the rays strike either before or after they come to a focus. Therefore for the best definition the surface of the target should not be at an angle of forty-five degrees, and the double focus tube, which has two reflecting surfaces, both of which can be cooled in the way previously shown, is to be avoided as the definition is always bad. In practical work we should be careful to place the tube in such relation to the patient as to see the oval figure at an angle to reduce its length. If we make the surface of the target at right angles with the cathode discharge, this strikes a fairer blow and the tube is very bright, though it has serious objections, because the available field is annular on account of the cathode shadow. Nor does an annular cathode overcome the difficulty, partly because this form of cathode does not bring the discharge to a good focus, and partly because when the X-rays are sent back in the direction of the cathode there is less light. — Electrical Review, December 29, 1897.

NOTE 9 — DIRECT-ACTING, NON-REFLECTING FOCUS X-LIGHT TUBES

Roentgen's reflecting platinum anode tube in some of its modified forms is now practically the only type used, because it gives so much light, but the older type — where the cathode discharge went forward to the wall of the tube, there producing X-light, which was transmitted in the same direction instead of being reflected — has always had a fascination because in looking with the eye of the mind at what takes place in such a tube, there is seen a more symmetrical movement in the molecules of the residual gases than is possible in the reflecting type. If, however, an attempt is made to get good definition by focussing the cathode discharge upon the glass it is at once destroyed nor will cooling preserve it. In their present form such tubes are not practical. In Note 6 it was said, with powerful generators, platinum would be permeable, and a tube was mentioned with a cooled platinum disk forming that part of the wall on which the cathode discharge was focussed. Meanwhile, for ordinary generators and potentials producing the rays of such wave-length as will distinguish markedly between certain tissues of the body, an opening can be made in this platinum disk and closed with beryllium,[9]

[9] Note added 1903. — These direct-acting tubes with a window made of a metal with a low atomic weight are not economical of current, as Lodge has shown the target

which having an atomic weight of nine, one-third that of aluminum, is transparent and at the same time makes a good target on which to receive the focus of the cathode discharge and as a window for the X-light to come through. There are mechanical details in this tube which, requiring woodcuts to illustrate them, will be described more fully in a subsequent note.

Electrical Review, December 29, 1897.

NOTE 10—SCATTERED X-LIGHT

In a previous note the wave-length was said to depend on the potential and degree of exhaustion in the tube: a low potential and vacuum giving waves of such length as to make strong contrasts between bones and soft tissues in the human body; a high vacuum and potential giving less contrast, because the shorter waves generated went through the bones also. To see through greater thickness and yet have marked contrast, increasing the amperage was recommended, thus keeping the wave-length unchanged, but increasing the amount of light, and it was stated this did not much change the relative transparencies within the limits of an ordinary apparatus. It is the object of the present note to show why there is any change in the

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should have the highest possible atomic weight. Reasons for this were given in American Journal of Science, November, 1900, in a paper entitled The Cathode Stream and X-Light, reprinted as Note 109 A. Briefly stated, one reason is: Atoms are not solids. An aluminum atom, having fewer sub-atoms than a platinum atom, does not present so dense a wall to the impact of a cathode stream particle, which in consequence is stopped less abruptly, thus giving rise to less X-light and more light of longer waves, useless for our purpose.

relative transparencies. In attempting to use ordinary light with an X-light camera, made to find stones in the bladder, a 20,000-candle-power arc was so enclosed no light could escape into the room except through a small hole directed toward the abdomen. Though this light came through the tissues, it was too scattered to show structure, and this is naturally what happens with X-light, though in a less degree, because of its shorter wave-length. If these waves are generated of such a length as to lose all detail in the soft tissues, the bones may be very dark by contrast. If we try to make the bones lighter by increasing the amperage, keeping the potential the same to prevent altering the wave-length, we can make them very bright, with a large condenser discharged rapidly, but the brightness is due to scattered light which does not show any more of their structure. If more details are wanted in the bones, we must develop waves of shorter length, and when this is done by increasing the potential and the vacuum the bones can be made as bright as before and yet their structure will show because the light is less scattered. Now by further increasing the amperage, they may be made still lighter though the structure will be lost, because we are using enough light to come through the denser parts, but being scattered light it shows no detail.

Electrical Review, January 5, 1898.

NOTE 11 — MAKING THE COOLED ANODE OF OTHER METALS THAN PLATINUM

In describing the cooled target tube, the cost of the platinum was mentioned as a possible objection, and a promise was made to describe a method of reducing the expense. In some experiments to determine what metal was best for that part of the anode receiving the cathode discharge, a copper anode was used, the only platinum being the face of the target and a short tube, where it was sealed into the glass. As Kirmayer & Oelling find no difficulty in this construction, there is no reason why it may not be employed. By soldering different metals to the end of these anodes, an attempt was made to determine which was best to use as a target in a reflecting focus tube. Tubes work so differently it is difficult to compare them. To overcome this, the metals to be tested were arranged around the periphery of an iron disk, which, being revolved by a magnet, allowed any one to be quickly brought in position to receive the cathode discharge. Even then it was difficult to determine the relative values;[10] but at present platinum seems well adapted to the purpose. — Electrical Review, January 5, 1898.

NOTE 12 — BURNING FROM A VACUUM TUBE NOT GENERATING X-LIGHT. TESLA'S SCREEN

Mr. Tesla long ago told us how to prevent burning, and as his statements are always facts of nature, no proof is required to support them. His fact is here approached from another point of view. A tube was exhausted to such a degree no X-light could be produced with the potential employed, the discharge going around the tube. By exposing a hand it was severely burned.[11] — Electrical Review, January 5, 1898.

[10] Note added 1898. — On account of amalgamated gas.

[11] Note added 1903. — The experiments on guinea pigs published in Boston Medical and Surgical Journal for February 21 and 28, March 28, 1901, and January 9, 1902,

NOTE 14—A REASON WHY LENARD'S X-LIGHT WAS FEEBLE

Thompson and Anthony's book on X-rays contains a cut of a Lenard tube. The anode is behind the cathode, encircling its stem, the aluminum window being connected with it. For one experiment this ring cathode was used in a Roentgen reflecting focus tube. Soon after the generator was started the current strained the medium between the cathode stem and the annular anode to the point of rupture. The cathode stem then began to vibrate rapidly, the range of movement being as great as the annular anode permitted. The generation of X-light was at all times feeble, because only a little of the force of the current was expended in sending the cathode discharge forward to the target, the remainder going toward the ring.

Electrical Review, January 12, 1898.

NOTE 15—DOES THE CATHODE STREAM GO FORWARD IN A HIGH VACUUM?

In paragraph 57 of the work mentioned, the statement is made that Crookes found at a low vacuum the cathode discharge taking place in the direction of the anode, even curving from the concave surface to reach an anode behind. At a high vacuum this did not take place, the stream going straight forward, without regard to the position of the anode in lines perpendicu-

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showed X-light could burn; and all an aluminum screen could do was to protect the patient from these radiations, which it absorbed -E. Thomson-, and when grounded, from electric influences, among which may be mentioned charged bodies, electrons and ether strain. .. ..

lar to the surface. In previous notes the form of the cathode stream and its relation to the surface has been considered. In this one, only the direction of the stream in regard to the anode will be mentioned. For one experiment a tube was made like the one described in Note 14, only the ring anode was so large the strength of the medium between the encircling anode and the stem of the cathode was nearly equal to that between the concave surface of the cathode and the usual reflecting platinum target. This tube is shown in Plate 5, Figure 1. When the encircling ring was the anode, no discharge went forward from the concave side of the cathode to the target; and so far as the production of X-light was concerned, that bulb might have been removed without effecting it, for the whole interior was dark, while the bulb containing the ring anode was full of X-light, though the definition was necessarily imperfect.[12] Evidently, therefore, at the degree of vacuum used in producing X-light, the position of the anode in relation to the cathode may be of importance.[13]

Electrical Review, January 12, 1898.

NOTE 16 — IS X-LIGHT STRONGEST WHEN THE ANODE IS THE SOURCE?

In the work mentioned, Roentgen, Lodge and Rowland are quoted as saying for the best generation of X-rays the surface on which the cathode discharge is received should be the anode. Early in the history of X-light, finding

[12] Note added 1898. — On account of the wide radiant area.

[13] Note added 1903. — See also Note 102 and Plate 40, Figure 75.

the rays were generated at both anode and cathode, a tube was constructed on the principle shown in Plate 6, Figure 2, in which the rays produced by the anode impact, when this was acting as a cathode, were focussed on the back of the platinum target and sent out of the field,[14] avoiding in this way injury to the definition from the second light source. If we connect the hollow cooled target of this tube by a wire to the anode it becomes an anode. Now, while looking into the fluoroscope, if we cut the wire, the target has no metallic connection with the anode, and yet the useful light given off from the front of the target is not sensibly diminished. In trying to reconcile this with accepted views a tube was constructed with terminals at about the places marked ET in Plate 5, Figure 1. Any one could be made an anode. As the anode got out of line, so the target did not come between it and the cathode, the light diminished, until, as stated in Note 15, when the anode was on the opposite side of the cathode the target was no longer a source of X-light. Therefore it may be safe to make this statement. If the target for the cathode discharge is in line between the cathode and the anode, practical considerations do not require it to be an anode. If powerful generators are used to excite the tube, it is better not to have the target the anode, for a cooled target having no metallic connection with the terminals does not blacken the tube as quickly as when it has the function of an anode.[15]

Electrical Review, January 12, 1898.

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[14] Refer to Note 4.

[15] Note added 1899. — For the advantages refer to Note 31, for the objections to Note 66.

NOTE 17—THERE ARE TWO SOURCES OF X-LIGHT IN EVERY X-LIGHT TUBE

Soon after Roentgen described his focus tube, Prof. E. Thomson applied this principle to the alternating current, inventing his double-focus tube[16] for use with any kind of generator. Though this gives two radiant points, they are near together, and by cooling the target and accurately focussing both cathodes, the two areas may be made very small and so near together as to improve the definition.[17] This principle of Professor Thomson's is a fascinating one to the mind of a prudent experimenter, as it utilizes X-light which would otherwise be wasted, while in the tube shown in Plate 6, Figure 2, when used with alternating currents, the waste goes on, though it produces no injurious effect, as the secondary light source, which is always present in every tube, even when excited by the so-called unidirectional currents, is sent out of the field. Some types of generators -as static machines and ordinary induction coils- are said to give unidirectional currents in a vacuum tube, but this is probably an error of observation, for with all powerfully excited tubes with two terminals a second light source is painfully apparent.

Electrical Review, January 12, 1898.

NOTE 18 — THE WAVE-LENGTH DEPENDS UPON THE VELOCITY OF THE IMPACTS UPON THE TARGET

In earlier notes the wave-length was said to depend upon the potential and the vacuum. It

[16] This tube is a modification of Roentgen's. See Note 163.

[17] Refer to Note 65, Plate 31, Figure 60, for a tube of this kind.

has been since stated the wave-length might possibly depend upon the potential, but it was difficult to see what the vacuum had to do with it. The proposition is therefore given in another form. The wave-length of X-light depends upon the velocity with which the cathode discharge strikes the target. The amount of light depends upon the amperage utilized[18] at the target. From the foregoing it is evident the type of generator is of no moment for producing light of the proper wave-length for medical use, except from a mechanical point of view, for sufficient electro-motive force and amperage can be obtained from any one, and the same effects can be produced upon the target either with the rapid discharges of a Tesla coil with a small condenser, or the slower discharges of an ordinary coil and a large condenser, or with a static machine having a sufficient number of 30-inch plates.[19]

Electrical Review, January 26, 1898.

NOTE 19 — MOVABLE CATHODE TUBES

Plate 7, Figure C, shows the tube mentioned in Note 4; Plate 8, Figures D and DI, that described in Note 9. The hole in the platinum is one-eighth of an inch in diameter. This is closed by a more transparent metal to allow the X-light to pass. When a very small radiant point is desired without adjusting the cathode,

[18] Note added 1903. — The word utilized is important here because a large amperage may be used, enough to melt the target without producing X-light, the force of impact of the cathode stream particles not being great enough to yield shorter waves than those of ordinary light. Refer to Notes 30, 45, 64.

[19] Consult also Notes 159, 160, 163.

a laterally movable diaphragm with a small hole is placed as shown by the dotted line, its opening being brought exactly opposite the place of impact of the cathode discharge on the transparent metal window target. To avoid risk of tearing the sealed-in platinum cell from the glass by the expansion and contraction of the window-target, the form shown in the figure is adopted, the depression around the central area acting as a spring allowing this part to expand and contract without injury to the seal. When moderate potentials and vacuums are used the lead disk attached to the rim of the celluloid window cuts off all X-light except what comes through the opening in the diaphragm, producing the best conditions for good definition, — a small, radiant area and no secondary light source, on which points and on the use of light of a proper wave-length we must depend for seeing details in the soft tissues of the human body. Since the cuts were made the cooling cell has been made in a separate piece and attached by a rubber tube, as this reduces the weight of the platinum.

Electrical Review, January 26, 1898.

NOTE 20 — LOADING THE CATHODE GUN

The cathode has already been compared to a rapid-firing gun, and an attempt has been made to show the importance of adjusting its range to produce the required effect upon the target. If the best means of loading are not considered, the firing will be irregular and ineffective; therefore in this note an attempt will be made to show how important it is to place the cathode gun in correct position for continuous loading. The experiments relate to a bulb-shaped vacuum tube with two terminals. Plate 9, Figure 5, shows a tube in which both gun and target, being movable, can be adjusted relatively to each other to insure correct positions, and while maintaining these positions can be moved to different parts of the tube to find the best place for loading. If the cathode is placed in the position shown in Plate 9, Figure 5, there is most light; if placed as shown in Plate 9, Figure 7, there is less light; if placed as shown in Plate 9, Figure 6, we shall find this the worst position of the three. In early experiments to construct an efficient focus tube, after trying many forms it was concluded there was a critical position for the cathode, a little movement on either side of which distinctly diminished the amount of X-light. Provided this observation is correct, what is the cause? Is it not the almost-forgotten anode, which, since Roentgen's discovery, we have hardly considered, except to make it dense enough to stand the impact of the cathode discharge? Nineteen years ago Spottiswoode wrote, "Each terminal pours forth its electricity to satisfy its own needs and only to a secondary degree to satisfy the needs of the opposite terminal." Even if this is not wholly true, we should not lose sight of the fact that in a vacuum tube with two terminals, molecules are being driven off from each, and when those coming from the cathode are to be used to produce X-light, we should be careful those coming from the anode do not cause unnecessary collisions and retardations. In studying the rushing sweep of the molecules along the walls of the tube toward the cathode end, we can readily see, with the cathode in the position shown in Plate 9, Figure 5, they will be delivered in good form to load the cathode gun, while with the cathode as shown in Plate 9, Figure 6, they sweep behind it and must be brought forward before they can be used again. If the cathode is placed as shown in Plate 9, Figure 7, they must to a certain extent interfere with the molecules which are rushing out of the mouth of the cathode gun on their way to the target. — Electrical Review, January 26, 1898.

NOTE 21—THE APPEARANCE OF AN UNCOOLED ANODE IN A ROENTGEN REFLECTING FOCUS TUBE

In attempts to find out what happens in a Roentgen tube considerable time was spent in studying the appearances of anodes spoiled in use. Through the courtesy of Kirmayer & Oelling an opportunity was presented to examine the tubes returned to them for new anodes. Where the force had been only sufficient to gently melt the anodes, the edges of the holes were rounded as shown in section in Plate 10, Figure 8. If the force had been enough to quickly give the molecules a freer range, the holes made in the platinum had edges toward the cathode, and were rough and jagged where the metal stiffened into points and ridges, as shown in section in Plate 10, Figure 9. The bombarding molecules from the cathode had not driven the platinum in front of them, as we might suppose when our minds are fixed upon the cathode. They had been opposed by another force operating in a contrary direction. As this force increases with the degree of excitement in the tube and operates about perpendicularly with the surface of the anode even when, as in a focus tube of the reflecting type, this is at an angle with the cathode, it is doubtless the molecular rush of the forgotten anode.

Electrical Review, February 9, 1898.

NOTE 22 — COOLING THE STEM OF THE ANODE

Dr. F. H. Williams has recently shown me the tube illustrated in Plate 10, Figure 10. It consists of an aluminum bulb with a rubber stopper, through which passes a glass tube with the anode sealed in. Inside the glass tube is a rubber tube, through which water was admitted, the waste escaping between the tubes. This tube goes back to the time when only newspaper accounts of Roentgen's discovery had reached this country, showing that cooling the stem of the anode had been thought of before the cooled target tube was described in these notes. The inventions are in a way different, because the amount of force used was too small to injure the anode, the object being to prevent the warmth of the anode from injuring the rubber stopper, while in the cooled target tube the surface on which the cathode discharge was received was cooled, because with the great force frequently applied, it would otherwise promptly have melted.

Electrical Review, February 9, 1898.

NOTE 23 — OXYGEN IN A VACUUM TUBE

In searching for new lights by which to see that remarkable fact of Mr. Tesla's that molecules of the residual gases went out through the glass walls, a number of experiments with different gases were tried. Oxygen was chosen for one of these on account of its reasonably high molecular weight, and because there was reason to believe these molecules would be easier than some others to break under electric stress into electro-negative and positive groups, a matter of importance, because X-light and smashed molecules go together.[20] Whatever may be thought of this statement and of another, that it is broken molecules which go out through the glass, the experiments are of interest, for a Roentgen tube, in which the residual molecules are largely oxygen, is very bright and easy to exhaust, and also we have in stored-up oxygen the best means now known of regulating the vacuum. A simple way to prepare this stored-up oxygen is this: Mix four parts of chlorate of potash with one part of manganese dioxide. Heat them gently in a test tube until they form a coke-like mass. When cool, this is broken up into suitable pieces and placed in another tube, the end being sealed to exclude water vapor and gases. When required for use the tube is opened, a few grains of the mixture taken out and placed in a small bulb attached to a vacuum tube, which is then placed on the pump and exhausted to a high vacuum, heated to lower the vacuum, again pumped and heated, and this process continued until heating no longer lowers the vacuum. The little reservoir of stored oxygen is gently heated until the vacuum comes down. The pump is worked to raise the vacuum and the process repeated a few times. The tube is then sealed off. When by use the vacuum has risen, the reservoir of oxy-

[20] Refer to Notes 109 and 109 A.

gen is gently heated while the tube is excited, until the vacuum is at the degree required for the special work on hand. Such a tube phosphoresces strongly after the current is turned off, and presents several interesting appearances which will be described if suitable half-tones can be made. — Electrical Review, February 9, 1898.

NOTE 24 — OTHER REASONS WHY THE VACUUM RISES

When an X-light tube is kept hot during exhaustion the vacuum is sufficiently free from water vapor to disregard its condensation on the walls as a cause for the vacuum altering in use. After this tube has been used the vacuum rises. It can be lowered again within certain limits by heating. Rest for weeks or months will also lower a vacuum. Why should heating and rest do this? It has been said heating drove gases out again from the substance of the glass, but not that rest would do the same. Perhaps it may, though in addition to the causes mentioned there is another. In a vacuum tube exhausted in the ordinary way we always have oxygen as one of the residual gases. Under electric stress the molecules of this gas are smashed, and as some of the new molecules contain a greater number of so-called atoms, the number of molecules is less, and therefore the vacuum must be higher. Now, one of the characteristics of these new molecules is, that heat decomposes them into ordinary oxygen molecules, thereby increasing the number, and therefore heat lowers the vacuum. This change of the stress molecule back to the normal type also takes place at ordinary temperatures if we wait long enough, therefore rest lowers the vacuum. There comes a time, however, when with ordinary vacuums neither heat nor rest will lower them enough to be of practical use, because other means are at work. The larger the proportion of oxygen molecules to those of nitrogen, the longer will heat and rest prove efficient, and this is one, though a not important, reason why this type of vacuum was recommended in Note 23. — Electrical Review, February 16, 1898.

NOTE 25 — AN ATTEMPT TO PRODUCE HOMOGENEOUS X-LIGHT

In Note 6 it was said the wave-length of X-light depended upon the potential and the vacuum. In Note 18 the fact was stated in another way, — that the wave-length depended upon the velocity with which the molecules struck the target. In this note the matter is looked at in a different light. With the same potential and vacuum and distance between the cathode and target, the wave-length depends upon the weight of the bombarding molecules, which belong to what are generally considered two distinct classes, metallic and non-metallic. They are the molecules of the cathode and of the residual gas. Emerson has said the atoms march in tune, and this should be remembered when we wish to generate homogeneous X-light. The gas and metal molecules should be tuned to strike the target with the same velocity, for the light to be produced there is simply music of the ether, with a pitch too high for our eyes until, through the keener perceptions of a fluorescent screen, it is brought down to our range.

The simplest way to tune the molecules of gas and metal is to fill the tube with a gas whose molecules have the same weight as those of the metal of the cathode. It is also evident with a given potential, vacuum and distance, the lighter the molecules the higher the velocity with which they will strike the target. In other words, the lower the molecular weight[21] the lower the potential we can use to produce X-light of a given wave-length. This is of importance, because with the present apparatus high potential means bulk and weight. A few experiments, which appear to bear on the matter of molecular weight, may be of interest. The experiments were tried in several ways, but for simplicity only one will be mentioned. A number of tubes were made alike in every respect, except that the metal of the cathodes was different. For brevity, the series is limited to aluminum, zinc, tin, platinum. A moment's consideration will show the relation of their weights and why they were selected. In all the cases with the moderate potential used, the aluminum gave the best results in light, the difference between it and platinum being marked. But, as already stated, the light also depends upon the bombardment of gas molecules, so another series of experiments was tried, arranging the gas molecules to nearly correspond in molecular weight with those of the metal of the cathode. For example, with aluminum, oxygen was used, the molecular weights being approximately 27 and 32.

For one experiment two metals of high weight were selected, one easily acted on by oxygen,

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[21] Sub-atomic weight. Refer to Notes 109 and 109 A.

the other with difficulty. As there was very little difference in the results, oxidation did not seem to play an important part. The two metals were lead and platinum. It would have been interesting to try the lighter metals than magnesium for cathodes, for example, beryllium, but it was impossible to get a piece large enough. It seems fortunate metals of low weight are best for cathodes, because the metals of the cathodes are always deposited on the glass walls of an X-light tube, in which position, if they had high atomic weights, they would interfere with the passage of the light.

Electrical Review, February 16, 1898.

NOTE 28 — BAD DEFINITION CAUSED BY DANCING OF THE RADIANT POINT

If we tune the generator and tube together, and adjust all the conditions, the radiant area on the platinum can be seen as a minute red-hot oval spot surrounded by a colored halo. To see this the target must be placed as directed in a previous note, not at the theoretical, but at the real, focus of the cathode discharge.[22] By throwing the generator out of tune with the tube the colored area can be made to dance around the red-hot spot. Of course, the whole area from which X-light is being given off is moving, the red spot appearing to keep still because the metal does not have time to cool. With a moving radiant point we cannot get good definition, for the shadows cast by an object in the path of the light shift their position, producing a kind of composite photograph, made up of

[22] Refer to Notes 1, 2, 3.

many images. The effect is the same as though the tube were moving during the exposure. One of the most frequent causes of this phenomenon is the lateral discharge which takes place between the cathode and the glass walls when the tube is out of tune. In experimenting with different metals for cathodes in tubes otherwise alike, the lateral discharge was most frequent with metals of the highest atomic weight. This frequently made it a matter of some care and time to compare different tubes. Lead, which has an atomic weight of 207, was frequently deposited on the glass, thus acting as a second cathode, deforming the cathode stream. Of all the common metals heavier than aluminum, zinc gave the least trouble and brightest light. With an increase of the exciting current the lateral discharge became more evident, showing it was caused by the difficulty which the discharge had in escaping from the cathode in the normal direction. Even throwing the tube out of tune, by increasing the condenser capacity, was enough to bring about this result.

Electrical Review, February 16, 1898.

NOTE 29—ON HARMONY BETWEEN TUBES AND GENERATORS

The maker of a tube should know the form of the generator by which it is to be excited, and when, after trial, they are found to be in tune, the tube should never be used on any other generator. For example, if a tube is adjusted to give good results with a static machine of eight plates, 28 inches in diameter, run at a speed of 200 revolutions a minute, a common type and speed, and is then excited by an eight-inch coil with a 10-

microfarad condenser, the current being broken 1,200 times a minute, also a common type and speed, the tube will be useless in a few minutes because the vacuum has been lowered.[23] If the excitement of the tube is continued until after some hours the resistance has risen sufficiently to admit of the production of radiant energy of suitable wave-length, on exciting the tube on a properly arranged alternating-current dynamo, in a few minutes the vacuum will again fall, while the wave-length of the radiation will increase until it consists chiefly of ordinary light; the waves will be too long to go through the tissues of the body without being scattered.[24] The cause of these changes is increased amperage, and this is one explanation of the phenomena to be mentioned in Note 34. On the other hand, increased electro-motive force will produce the same result. If we take a tube which is in perfection for the static machine already mentioned and excite it with one having plates four feet in diameter, using a slow speed and a less number of plates to prevent increasing the amperage, in a few minutes the vacuum will have fallen so much, several hours' running will be required to bring it up. When it has risen to the proper point again, if we place the tube on a machine with six-feet plates, taking the same precautions with the amperage as before, the same result will be produced. If both increased amperage and electro-motive force are used, a few seconds will bring down the vacuum until eight hours' running on this large machine will be needed to bring the resistance

[23] Part of the gas comes from the terminals.

[24] Note 10, 1898.

up to the proper degree. With a powerful Tesla high-frequency coil it is possible to quickly bring up the resistance, because the amount of force which can be sent through a tube with one of these generators in a short time is enormous in comparison with what can be obtained from even a large static machine. On this account Tesla coils[25] must always be used for photographic work where attempts are made to get instantaneous views of the heart; but as the light is at present less steady, and as they raise the resistance so rapidly, they are less satisfactory for visual work than large static machines, which, sending the surges less frequently, still give light enough to see properly, and using less amperage in a given time, raise the resistance less rapidly and require less attention when run continuously.

More space has been used in describing this matter than has been taken for much more important observations, on account of its immediate practical bearing. Operators are annoyed by the working of new tubes, and tube-makers are blamed unjustly. At present, when an order is given for a tube the electro-motive force and amperage of the generator on which it is to be used should be given. On the other hand, for the future, tube-makers should be provided with generators having higher electro-motive force and greater amperage than those on which the tubes are afterward to be used, otherwise they will continue to spend hours in vain attempts to

[25] Note added 1903. — By using " an induction coil " -as distinguished from a high-frequency coil- without a break, as recommended in Notes 159 and 163, more amperage than any tube can bear can be delivered to it.

make tubes which will not fall when their customers use more powerful generators. The correct way to pump a tube is first to exhaust it with a mechanical pump,[26] then with an automatic mercurial pump keeping the tube hot, and from time to time for a minute sending through it a stronger current with a higher electro-motive than will ever be used on it afterward; the object being to force into the circulation particles from the terminals and walls. We probably do not know all the causes for the fall in a vacuum, but experiments have shown some of the particles of gas which are forced into the circulation come from the terminals, because, if these are kept as near the freezing-point as possible by means of cooled terminals a longer time, a higher electro-motive force or a greater amperage will be required to lower the vacuum.

Electrical Review, October 19, 1898.

NOTE 30—THE WAVE-LENGTH DEPENDS ON THE TEMPERATURE

In Note 18 the wave-length was said to depend upon the velocity of impact. In this note temperature is considered. Plate 11, Figure 30, shows a modification of the tube described and figured in the Electrical Review for December 1, 1897. There is a receptacle for a thermometer to show the temperature of the water escaping from the hollow target. If this water is kept at five degrees Centigrade, a higher voltage is required to produce X-light of a given wave-length than when the water has a higher temperature. On the other hand, by using a lower voltage or

[26] For a simple hand-pump refer to Note 173.

vacuum and increasing the number of impacts on the target, by increasing the amperage, an uncooled target can be made so hot it radiates ordinary light, and yet the tube will not yield X-light because the force of impact is not great enough to heat the individual particles of the cathode stream sufficiently to produce the short vibrations which are X-light. In practice a very high temperature of the target is not desirable because the shock of impact of the rushing particles of the cathode stream on such a target is less violent and therefore less efficient in producing the enormous temperature of these particles which is essential. We are unconscious of this temperature because at present there are no means of producing such rapid vibrations in a sufficient number of particles to constitute a mass such as we think of as a source of heat. By using a very high vacuum and voltage, a temperature [27] perhaps higher even than our sun can be produced, one at which some of the so-called elements can be decomposed, and here the vacuum tube opens a new world.

Electrical Review, August 3, 1898.

NOTE 31—ON HAVING THE TARGET SEPARATE FROM THE ANODE AND NEARER THE CATHODE

In Note 18 it was said the wave-length depended upon the velocity with which particles

[27] Note added 1903.—The word temperature is not used to express a state of vibration due to combustion. It is employed to indicate a more persistent state of vibration from impact than the single pulse of the Stokes theory. Refer to Notes 65, 75, 109. For Rowland's criticism of Stokes' theory refer to The Physical Papers of Henry Augustus Rowland, page 584, Johns Hopkins Press, 1902.

from the cathode struck the target. The force of impact varies and is less at three inches than at a nearer point.[28] Therefore when, as shown in Plate 6, Figure 2, Note 16, the target is between the terminals and nearer the cathode, the velocity of impact should be greater than when the target is the anode. By adopting this construction advantage may be taken of the high initial velocity due to the difference of potential we can maintain by having the terminals three inches apart, and yet by placing the target at one and one-half inches from the cathode, the molecules may be made to strike it with a higher velocity than they would if they continued their flight to the anode and used this as a target. So with a given voltage we should be able to generate light of a shorter wave-length or of the same wave-length with a lower voltage. The latter is a matter of some consequence, as it should enable a smaller generator to be used.[29] Another possible advantage is the shielding of the cathode discharge from the anode rush described in Notes 20 and 21. Only tubes with more than one terminal are considered, because this is the type in common use. Mr. Tesla's tubes described in Thompson and Anthony's work on X-light, though a much more interesting form, are at present rarely employed outside the laboratory of this great discoverer. A modi-

[28] This is contrary to the general opinion, which is that the nearer the terminals, the higher the resistance. Refer to Note 136 C, where an experiment is mentioned showing the resistance rises as the terminal distance increases. The common error arose from neglecting to consider the condition of the gases of the terminals.

[29] Note added 1903.—For the disadvantages consult Note 66.

fication of one of these was shown in Plate 8, Figures D and DI. This can be used either as a single or double terminal tube, though it was constructed to combine Mr. Tesla's single electrode with the Crookes and Roentgen plan of bringing the cathode stream to a focus, and to these was added the cooled target. As it has been said the wave-length depended upon the voltage, it might be supposed with the very high potential which can be maintained when having one terminal only connected with the generator, the tube might not be suitable for generating light of the longer wave-length required for distinguishing between the soft tissues of the human body; but this is of no moment, for it is only necessary to use a lower vacuum, thus making the wave-length longer by diminishing the velocity of impact. It is practically impossible to get so high a voltage the wave-length cannot be controlled by the degree of the vacuum, and when it is high enough we can realize a dream and discard the vacuum tube as an essential in the production of this light.

Electrical Review, August 3, 1898.

NOTE 32—ON THE SIZE OF CATHODES

For X-light to be of much use in medical diagnosis it is necessary to have a generator of sufficient power to send the light through the adult body at a distance of at least three feet from the radiant area on the target of the tube. Shorter distances produce marked distortion of the internal organs, a matter of grave importance in studying the heart and determining its real size in disease. This distortion is also a serious matter in estimating the relative sizes of organs lying in different planes, the one farther away being made to appear relatively too large. Six feet is a much better distance, but unfortunately there are no commercial generators powerful enough to furnish a proper light at this distance, and such an apparatus is necessarily expensive, costing one thousand dollars even when made at home. As three feet taxes the best commercial generators to their limit, it is necessary in using the fluoroscope to economize power by sending the electric surges as slowly as is consistent with a steady light.[30] Two hundred surges a minute are said to do this, but it is necessary to have twelve hundred a minute to have the illumination of the screen appear steady. As every surge must give force enough properly to illuminate the body, it is necessary to make each of as large an amperage as possible with the generator employed. This may be done by filling the condenser as full as possible in one-twentieth of a second, which is the maximum time force can be allowed to accumulate for a single surge. When an attempt is made to deliver this amperage from a cathode of ordinary size, the electricity seems to have difficulty in escaping from the concave side of the cathode in a normal manner. As a result the lateral sparking mentioned in Note 27 is produced. If

[30] Note added 1903. — As it is now known from the experiments on animals mentioned in later notes that X-light can produce death by its effect upon internal tissues, this is an additional reason why in fluoroscopic examinations the total quantity of X-light passing through the patient should be reduced as far as possible by the method mentioned, — by taking advantage of the duration of the fluorescent light produced by the shortest possible electric surge.

the cathode is placed in a tube at the end of the bulb and near the walls -as in ordinary commercial tubes before the defects of this position were discovered-, the glass is soon broken. To overcome these difficulties the cathode should be placed as shown in Note 30, Plate 11, Figure 30; Note 20, Plate 9, Figure 5, and instead of being less than an inch in diameter, which is common, it should be two inches or more. These large cathodes are not necessary with small generators. In conclusion, two things are to be made prominent: the cathode acts as a condenser; the size of the cathode should be in proportion to the size of the surges.

Electrical Review, August 3, 1898.

NOTE 33—PERFORATED CATHODES

At a certain stage of the vacuum only the edges of the cathode appear active. At a higher vacuum only the centre of the cathode seems to be the source of a cathode stream. These appearances have led observers and tube-makers to consider a small cathode as good as a large one. In previous notes attempts were made to prove the fallacy of this, and here a cut of one of the perforated cathodes used in the experiments is given. A glance at Plate 11, Figure 31, will show it has a solid centre as large as the average cathode, and a wide, solid rim. If only the edges or centre of a cathode were active, this one should be as efficient as though it was solid, but it is not. The cathode stream from it is broken up, and so little strikes the proper point on the target, this is not made red-hot by a current which would melt it with a solid cathode of the same size. The appearances of perforated cathodes of various designs are very beautiful, as are the figures they form on the glass walls. Both are worth careful study.

Electrical Review, August 3, 1898.

NOTE 35 — COVERING THE TARGET WITH ALUMINUM

If an X-light tube having an aluminum cathode and a platinum anode is examined after it has been used a considerable time, a deposit of two colors will be found on the walls. There is a more generally diffused purple deposit[31] from the cathode and a less generally diffused brown deposit from the platinum. Fortunately the latter deposit is less in front of the target, otherwise the amount of X-light yielded by the tube would be more rapidly reduced than it is by use. As the deposit does somewhat diminish the efficiency of the tube, covering the target with a thin layer of aluminum was tried. Such a target is shown in Plate 13, Figure 32. Plate 13, Figure 33, illustrates the same idea applied to a cooled target. It was hoped the platinum would act like the silver coating at the back of a glass mirror and prevent the loss by transmission which was supposed to take place when aluminum was used as a target. This experiment was tried two years ago, and little practical importance is now attributed to this form of target, for the inefficiency of aluminum is not so much due to its transparency to X-light as to a fact this experiment pointed out, — the individual particles of the cathode discharge are not raised to so high a temperature by the same voltage when they strike an aluminum target as

[31] Consult Note 87.

when they strike one of platinum or some allied metal, because the shock of impact being less sudden, heat is developed during a longer time and therefore never attains the maximum.[32]

Electrical Review, August 17, 1898.

NOTE 36 — DIAPHRAGMS FOR X-LIGHT TUBES

So many experimenters, the writer among the number, have invented the diaphragm for sharpening the shadows cast by objects in the path of X-light, it is a matter of some difficulty to determine to whom the credit belongs. The use of a diaphragm is described in an article by Leeds and Stokes in the Western Electrician for March 14, 1896. Considering the value of diaphragms, it is remarkable they should have practically gone out of use. As the power of generators is increased, it becomes more important to employ them, because, as stated in Note 17, a powerfully excited tube gives X-light over a large surface beside the radiant area on the target.[33] Diaphragms have always been made of metal,[34] but this is objectionable, because a conductor placed between the terminals of a tube reduces the length of the air-column and consequently the available spark-length, besides increasing the danger of puncturing the tube. To overcome these difficulties, lead glass over half an inch thick was tried. The arrangement is shown in Plate 12, Figure 34. It is a box of wood to hold the tube, and a frame for the glass

[32] Refer to Notes 109 and 109 A.

[33] Refer to Note 149 for improved diaphragms.

[34] Note added 1903. — With low-resistance tubes or those with automatic regulators, metal diaphragms are satisfactory.

plate, GP, which is one foot square with a three-inch hole in the centre. Covering the hole is another circular glass plate, DP, with a smaller hole in the centre. The latter plate can be removed and one with a hole of a different size substituted. The plates are held in contact by the screws, S and S, on the ends of the two arms, A and A1. As stated in the first article on this subject, this is the principle of Zentmayer's microscopic stage applied to another purpose. It enables the experimenter easily to bring the opening of the diaphragm in proper relation to the radiant area on the target. Plates 12, 13, Figures 34 and 35, show the tube-holder in position for examining a patient in a vertical position; Plate 13, Figures 36 and 37, its positions above or below the patient when he is lying down. The whole holder has a vertical range of six feet.

Electrical Review, August 17, 1898.

NOTE 37 — COOLING THE TARGET WITH METAL VANES

Instead of using water to cool the target when moderate amperage is employed, it is sufficient to put a copper stem into the hollow platinum target and expand the end into four vanes, as shown in perspective and section in Plate 13, Figure 38 A. — Electrical Review, August 17, 1898.

NOTE 39 — ON SOME ADVANTAGES OF HIGH ELECTRO-MOTIVE FORCE

For part of these experiments a comparatively high electro-motive force has been used, not, however, so high as employed by Trowbridge and Burbank, for none other than Great Jove has such potentials at command. One of the generators used contains eight revolving glass plates, each six feet, and eight stationary plates, each six and one-half feet in diameter. With this apparatus, which supplies a constant stream of electricity for any number of hours, it is practical to produce radiant energy of the wave-length required for the manifestation of X-light with a vacuum so low as to be equal in resistance to only one-sixtieth of an inch of air. This is a distinct advantage, because it is easier for the makers to furnish tubes with low than with high vacua, while by beginning with a low vacuum and a long spark-gap in series with the tube, there are longer working periods between adjustments of the vacuum with the oxygen regulator, for it is only necessary to shorten the spark-gap, as the resistance of the tube rises, to keep the character of the radiation constant. On these and other accounts generators of high electro-motive force are recommended for hospitals and office use, where portability is not important. — Electrical Review, October 19, 1898.

NOTE 41 — ON TEMPERATURE

As in every particle which is raised to a high temperature by its impact upon the target, the heat [35] must afterward decline, a tube that is generating Roentgen radiations of short wave-length is at the same time producing other radiations composed of longer waves down to, including and below those of ordinary light. This would be true, even if the particles of the cathode stream were annihilated after their heat of im-

[35] Note 30.

pact had departed. As, however, they rebound from the target, many of them striking the glass walls of the tube, this second impact not only produces luminescence of these walls, but again raises the temperature of the particles sufficiently to make a second source of Roentgen radiation -of longer wave-length- in all cases where the initial velocity was very high. This is one reason why powerfully excited tubes of the ordinary reflecting form give less perfect definition than less excited ones. In the former, the source of Roentgen radiation, not being confined to the target, consists of a bright central nucleus surrounded by a less bright halo, which is due to the rebounding particles striking the glass wall, as well as to the impact of the anode rush described in Notes 17 and 21; hence the importance of a diaphragm.[36]

Even with this means of reducing the area of the source of utilized energy, sharp definition is not obtained from a highly excited tube of the ordinary reflecting focus type, without too much limiting the field for anything but small objects, though by a modification, which consists in placing very near the target a piece of opaque metal with a hole in it through which the radiations must pass before they can reach the object to be examined, better results have been obtained. Figures of these tubes will be published later if the matter is of sufficient interest. With a direct-acting tube,[37] such as was described in Note 9 and afterward illustrated, the definition is always fine, however powerfully the tube

[36] Note 26.

[37] Direct-acting tubes are recommended in Therapeutics. Refer to Notes 166 and 167.

is excited, for a diaphragm with a small hole can be used without limiting the angle of the field, because the opening of the diaphragm is practically in the same plane as the source of the radiations. An improved tube of this type is shown in Plate 14, Figure 41 A, with sufficient detail to be understood by any one who has read the previous notes. However, there is one defect in this type. The impact of the cathode stream is upon aluminum or other light metal, therefore the wave-length of the radiation produced by the same electro-motive force is longer than in a tube of the reflecting focus type, where the impact of the cathode discharge may be upon platinum or heavier metals. In this connection it would be well to refer to Note 35.[38]

Electrical Review.

NOTE 41 A—X-LIGHT

Accepting from the beginning the statement made by Crookes many years ago that the cathode stream was composed of material particles, it seemed probable when Roentgen's discovery was announced that the wave-length of this new form of radiation would depend upon the temperature to which the particles of the cathode stream were raised by their impact upon the target. To test this, a tube was constructed in 1896 in which the metal target was hollow and could be cooled to any desired temperature. With tubes of this kind many experiments have been made, a few of the results which seemed likely to be of interest being published from time to time as a series of short

[38] Refer also to Notes 109 and 109 A.

notes in the Electrical Review during 1897-98. As they are scattered over a considerable period owing to the infrequent intervals available for preparing them, this summary of a few of the observations is now made. The cause of X-light is a high temperature of the originating particles. The wave-length of the radiation depends upon the temperature of these particles. Their temperature is due to several conditions: First, on the velocity with which they strike the target; the higher the velocity, the greater their temperature. Second, on the angle at which they strike; the greater the angle, the higher their temperature: a glancing blow not stopping the particles as suddenly, their temperature never reaches a maximum. Third, on the nature of the target; the denser the target, the higher their temperature, because the denser metals stop them most suddenly. Fourth, on the temperature of the target; the colder the target, the lower their temperature, — a target cooled below zero yields less light than when the temperature is several hundred degrees higher. On the other hand, many observations indicate that a temperature sufficient to soften materially the surface of the target diminishes the efficiency of the tube.

The velocity with which the particles strike the target depends upon several conditions. First, on the electro-motive force; the higher this is, the greater their velocity. Second, on the distance of the target; the greater the distance, the less violent the impact. Third, on obstructions on the way. These arise from various causes, — the degree of the vacuum; the form of the tube; the amount of harmony between the vibrations of the exciting current and the tube. One can get a good idea of what is going on in a tube when harmony is absent by looking out of a rear window of his town house during a wild snow-storm and watching in the narrow alley with its irregular sides the tempestuous rush of the snow as it is driven by the constantly changing reflections of the wind. Fourth, on the weight of the particles; a higher electro-motive force is required to deliver mercury particles at the target with a given velocity than those of aluminum and oxygen. The amount of light depends upon the quantity of energy utilized at the target; with a given velocity of impact the greater the amperage, the more the light.

Definition depends on several conditions: First, on the size of the radiant area on the target: the smaller this is, the better the definition; therefore the target should not be at the theoretical but at the real focus of the cathode discharge, the distance of which from the cathode depends upon the degree of repulsion between the particles forming the discharge, and is a result of the intensity of their charges. For the degree of exhaustion generally employed the focus is twice the length of the radius of the cathode curvature or double the theoretical distance. Second, on the steadiness of the radiant area, due to harmony and right proportion between the size of the cathode and the surges. Third, on eliminating other light sources, such as the second impact or that of rebound; the anode rush; the secondary source. Fourth, on the proper form of the tube. Fifth, on the use of a diaphragm. Sixth, on shielding the object to be photographed from aerial reflections in the room by using opaque metal plates closed as far as possible that no Roentgen radiation can reach the object except in straight lines from the target.[39] Seventh, on maintaining a considerable distance between the tube and the object, thus producing shadows of nearly normal size, a matter of importance in medical diagnosis. Eighth, on the quality of light: it is unwise to flood the tissues with light of any wave-length expecting thereby to bring out more detail. One of the reasons why a photograph often shows more detail than the fluoroscope is the smaller amount of light needed to affect the plate than to give clear images on the screen.

The form of tubes. — A tube should be of sufficient length to admit of the use of a high electro-motive force. The cathode should be in proportion to the surges; largest for large condensers, smaller for Tesla coils, where the amperage of each surge may be less on account of the rapidity with which they come. There should be a simple method of altering the vacuum to enable a large amperage to be sent through the tube for a long time without need of re-pumping.

The target. — This should be so constructed as to enable a large amperage to be used without injury and so arranged its temperature may be varied according to the kind of radiation desired, for in the same tube, by changing the temperature of the target and the velocity of impact, light can be made of any wave-length from the shortest Roentgen down to, including and below that of ordinary light.

[39] Note added 1903. — A matter still neglected.

Distance of the cathode. — This should be less for small than for large generators. The cathode, being a rapid firing gun, should be placed in the most efficient position for regular and rapid loading, being shielded from the anode rush. The walls of the tube should be of such curvature as to prevent the return stream from causing collisions with the normal cathode discharge as well as to insure a regular circulation. The target should be in a line between the cathode and anode, or the cathode discharge will not strike with efficiency. When the anode is behind the cathode the concave surface of the cathode gives off so little force that the target is no longer an available source of Roentgen radiation with ordinary generators, while a diffuse stream of particles rises from the convex side and by its impact upon the glass walls gives rise to a broad area of X-light. The cathode discharge is therefore not independent of the position of the anode. — The American X-Ray Journal, January, 1899.

NOTE 42 — ON GENERATOR TERMINALS IN OIL

Soon after Roentgen's discovery was announced, Professor Trowbridge cooled the discharge tube by oil. Mr. Tesla developed the method and published a figure of the apparatus. Like most of the early work, it has been lost, because the great experimenters will not take the time to say the same thing over and over. While using this method a peculiar phenomenon was observed which is here described. At the anode end of the tube the oil fairly boiled, not in temperature but in appearance, the surface being raised and in constant motion. This was striking, for no bubbles were formed. At the cathode end there was less disturbance, though a match appeared alive, darting to the terminal and rushing back again, repeating the motion at short intervals. When the tube was removed and the terminals placed 15 inches apart, the phenomena were very marked, the surface of the oil near the anode being raised a quarter of an inch. Here in the liquid dielectric was a similar process to what takes place in air; in other words, a liquid brush discharge.

Electrical Review, January 25, 1899.

NOTE 44—ON HYDROGEN AND OXYGEN

To make most of the light of short waves use hydrogen, because the same electro-motive force causes its particles to strike the target at a higher velocity, and therefore they are raised to a higher temperature, producing more short waves. In this case the target should be of the most dense metal, because, as stated in Note 35, the shock of impact is more sudden, the heat in consequence reaching a higher degree. To generate light of mostly longer waves use oxygen, which, being heavier, strikes the target with less velocity when the electro-motive force is the same. The particles are therefore not raised to so high a temperature, the waves being in consequence longer. Oxygen has one advantage for a tube with an uncooled target—it does not disappear so rapidly, the vacuum requiring less frequent adjustment. These statements apply to the ordinary types of commercial apparatus. With generators of moderate electro-motive force, large amperage or enormous frequency, other considerations come in.

Electrical Review, January 25, 1899.

NOTE 45 — ON HARMONICS

After reading the notes published in this journal it is desirable to add a few words on some points already touched upon. The wave-length of the X-light was said to depend upon the velocity with which the particles struck the target and upon the temperature to which they were raised by the force of the impact. As these particles are small the heat declines rapidly, the train of waves being short, the length of the waves increasing as the heat declines. The amount of X-light was said to depend upon the amperage utilized at the target, and as this is not the same as saying to increase the light it is only necessary to increase the amperage, the necessity of harmony between the tube and generator was considered, a matter which each new day of experience showed to be of prime importance. For example, it is possible to use the entire output of the large Holtz machine mentioned, probably the most powerful of its type, and not get as much light from a tube as when it is excited by a very small machine of the same kind. Perhaps no electrician but Mr. Tesla realizes the imperative necessity for harmonics for economically converting a long into a short vibration. The remarkable photographs he has shown in this journal of electricity converted into light are due to his recognition of this principle.

The poets are the true seers, and the discoverers whose minds are most like theirs are those who first catch glimpses of remotest laws. Emerson has already been quoted as saying "the atoms march in tune." This remark is again mentioned as showing the necessity of adjusting the apparatus to make the discharges from the concave terminal follow each other in regular order at periods which are harmonics of the wave-length of the X-light to be generated by the impact of these discharges on the target. Only in this way can the most light be obtained with the least amperage. Trowbridge has said an apparently single surge is composed of a multitude. The rate of these should be adjusted. So simple a thing as changing the condenser discharge with a static machine will make the difference between a well or badly lighted tube.

Electrical Review, January 25, 1899.

NOTE 45 A — AN X-LIGHT TUBE WITH AN INTERNAL DIAPHRAGM

In the accompanying Plate 16, Figure 42, is shown a form of internal diaphragm tube mentioned in Note 41. For most medical work the best definition is of less importance than the amount of light, but there are structures like the teeth and bones where it is valuable. By combining the internal diaphragm with the thick glass diaphragm shown in Plate 12, Figure 34, and in section in Plate 16, Figure 42, the definition is improved, and if, in addition, the part to be photographed is covered by a perforated screen of non-radiable material to prevent diffused light and reflections from reaching it, better results will be obtained.[40] The appearance of the tube when excited is shown in Plate 15, Figure 43. The second light ring is produced by the forces which come through the opening in the diaphragm. The wide dark ring is the shadow of the diaphragm. As everything

[40] Refer to Note 174 for receipt for making cloth non-radiable.

beyond this second light circle is cut off by the external diaphragm, practically all the waves which are used come through the central opening in the internal diaphragm, making the utilized radiant area always small.

Electrical Review, February 8, 1898.

NOTE 46 — THE ANODE RUSH

In Note 20 the anode rush was mentioned and its effects on the target figured in Note 21. Here is an illustration of the deposit it produces on the glass wall of the tube. Plate 18, Figure 44, is a half-tone from a photograph of a hollow target intermolecular regenerative tube which has been excited six hundred hours without re-pumping. Notice the central dark figure from the vicinity of which branched sprays, like lightning discharges, are given off. They are light on a dark ground. In addition to this central figure observe others, one on each side, also with branching lines. If the tube could be turned one-fourth of a revolution on its long axis the dark central deposit would be found near the place where the anode rush would strike the glass if it was given off perpendicularly from the surface of the target. This tube was purposely kept in harmony with the generator. In Plate 17, Figure 45, is shown a tube, which has been purposely run out of harmony to show discord as a visible metallic deposit on the glass, to illustrate the importance of tuning if we wish to economize power. Here the Crookes'[41] stream was kept flashing and

[41] Note added 1903. — Varley discovered the cathode stream and the force of its impact, therefore it should be called the Varley stream.

spattering. By using a powerful generator, carefully focussing the stream on the target and using a very light gas for the vacuum, one form of the anode rush may be seen. The platinum target must be very thick or it will be perforated in a moment, because the sudden stopping of the stream at the impact area of the target raises the platinum to vivid incandescence, small pieces of the melted metal being thrown off, remaining visible as minute stars even at a distance of half an inch in front of the target. These stars do not come off exactly perpendicularly to the surface, but spread.[42] — Electrical Review, February 8, 1899.

NOTE 47 — THE SEEHEAR

In looking at the heart or lungs it is a comfort to hear what they are saying and to be able to draw what is shown on the screen. The instrument here figured enables this to be done. As shown in Plate 19, Figure 46, it consists of a frame to which one or more flexible tubes are attached, terminating in the ear pieces of a stethoscope. The frame makes the rim of the sound chamber, the bottom of which is a sheet of some trans-radiable material,[43] with a hole in it, through which comes the sound. This sheet can be quickly changed for another, with a hole in a different place. As here shown it is approximately right for some heart sounds, when this organ is clearly outlined on the luminescent screen together with the dia-

[42] Refer to Note 3 for spreading of cathode stream.

[43] The words trans-radiable or radiable and non-radiable used in these notes are adopted from H. H. F. Hyndman.

phragm. The other side of the sound chamber is formed by the luminescent screen. In front of this is a sheet of celluloid or glass[44] to protect the screen, and over it a sheet of tracing cloth. This tracing cloth is an arrangement of Dr. F. H. Williams for making permanent records of his chest cases, by marking two fixed points on the tracing cloth and then sketching in outlines of dull or light areas. All parts of the apparatus are held together by the clamps. To show the position of the hole in the back of the sound chamber, a curved piece of non-radiable material is held by a spring clamp to the edge. This also serves as a reflector for sound waves. Plate 20, Figure 47, shows the arrangement in use. As the room must be dark, the photograph was made by flash-light. The same plan can be applied to a cryptoscope if graphic records are not required, in which case the examinations may be made in a light room. The size of the screen here figured is 12 by 14 inches. It is of the Kinraide non-phosphorescent type in order to get clear outlines of the beating heart. For women a smaller instrument can be used with advantage on account of the bust development, it being important to get the screen as near the heart as possible that its shadow may not be too large.

Electrical Review, February 8, 1899.

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[44] Note added 1903. — Glass, as shown in Note B -1896-, is essential to protect the observer from X-Light. With powerful apparatus it must be much thicker and made of very dense lead glass. Refer also to Note 144 and to Note 162, Plate 119, Figures 3 and 4.

NOTE 48 — ON SEEING AND HEARING YOUR HEART BEAT

By placing a mirror in proper relation to a luminescent screen, Plate 21, Figure 48, — a man can see his own heart beat. By combining the mirror with the instrument shown in Plate 19, Figure 46, he can both see and hear the heart. A nervous patient, whose organs are sound, is sometimes much comforted by being shown through his own eyes that all is well. In using this instrument the room should be made dark. Another instrument is in use in which both screen and mirror are enclosed in a case with a small opening for the patient's eyes. With this the examination can be made in a room with a light. It is, however, somewhat more clumsy than the one selected for illustration.[45]

Electrical Review, February 8, 1898.

NOTE 49 — THE GIRDLE OF AN X-LIGHT TUBE

In Thompson's interesting book, Light, Visible and Invisible, on page 265, a figure of an X-light tube is given, which is here reproduced in Plate 25, Figure 142. He says "as shown in Figure 142, the rays are emitted copiously right up to the edge of the plane of the anticathode." In Plate 22, Figure 49, a tube is shown in an excited state, which was figured and described in Note 16. What is usually called "the line of demarkation," is not a line between light and dark, but is a dark girdle about one-fourth of an inch wide, separating a brightly illuminated from a less illuminated area. The illuminated front area is not "right up to the plane of the anticathode,"

[45] For the earliest reflecting cryptoscope refer to Note B -1896-. For later forms refer to Notes 155 and 156.

but in front of it. If the target is cup-shaped with its concavity toward the cathode, the dark girdle will extend forward, being wider. This appearance is well shown in Plate 23, Figure 50. As the depth of the concavity in the target is increased, the front illuminated area is pushed more forward. This girdle can be made very narrow by using a flat target, a high vacuum and electro-motive force. As the illustrations to these last few notes are not all from photographs, allowance should be made for the personal element, though the artist tried to draw what he saw. In Plate 18, Figure 44, which is a photograph obtained after many struggles, the light branching lines did not show well on the half-tone. They were, therefore, retouched under a microscope in order to make them look natural. They are now a little too pronounced, though substantially correct. There are many appearances in vacuum tubes which would be described if it were not practically impossible to photograph them. Perhaps a way may be found. For example, many attempts have been made to photograph the corona of the tube, a phenomenon shown in the half-tone, Plate 24, Figure 51. But the appearances change so rapidly, the short exposure required does not give light enough to impress the plate. As it may be a long time before a photograph can be made of this, a cut is shown, taken from the wash drawing, to call the attention of others to the matter, which is of considerable interest from a theoretical point of view. This is also true of the appearance called the girdle, which will be discussed more fully, if good photographs can be made of it. — Electrical Review, February 8, 1899.

NOTE 50 — ROTARY TARGETS

In Note 11, January 5, 1898, a revolving target tube for experimental work was described. It is desirable to illustrate it in practical form, for if one does not care to use the cooled target tube shown in Note I., December 1, 1897, he will constantly be embarrassed by having his tube ruined by perforation of the target soon after it gets in prime condition. There is so much heat from the impact of the stream of radiant matter, no known substance can endure unless it is cooled. Platinum melts like ice in the sun when any considerable amperage is used. Increasing the thickness of the metal retards the inevitable, but a simpler way is to make the target revolve, thus bringing fresh surfaces to receive the cathode stream. In Plate 25, Figure 52, is shown such a tube in its simplest form, though here the revolving is not automatic. In Plate 25, Figure 53, the target is of full size. — Electrical Review, February 15, 1899.

NOTE 54 — MULTIPLE -X-LIGHT-PHOTOGRAPHY

In this journal for July 1, 1896, what appeared to be a new principle in radiography was mentioned; the taking of several photographs at one exposure. It has since been learned Prof. E. Thomson was the discoverer of this plan. As his method is not in use, renewed attention is called to it, for Professor Thomson is so occupied with other things he probably will never take the time to mention it again. What a surgeon wants, when he sends a patient to the Roentgen laboratory of his hospital, is to have a picture of the injury delivered to him in a few minutes, to use in his diagnosis. When he finds he must wait some hours, or a day or two, he instinctively avoids the method, his time being too valuable to lose. Professor Thomson's method enables him to get not one, but a number of positives in a few minutes, one of which will almost surely be better than would be the single plate taken in the usual way. The method consists in placing half a dozen sheets of bromide paper in a pile, and on top the part to be photographed. On developing all the prints together in one dish at the same time, six positives are obtained instead of one negative, and, by flooding these with alcohol, they can be dried at once.[46] — Electrical Review, February 15, 1899.

NOTE 55 — CONCAVE ANODES

There is nothing new in the idea of concave anodes, several experimenters having used them, notably Dr. Girdwood of Montreal. One or two appearances connected with them are mentioned which may be of interest. First, as shown in Note 49, the girdle is broader and further forward than with the flat anode. Second, instead of the corona, Plate 24, Figure 51, Note 49, there is a brilliant sun of smaller size than the anode and situated on the wall of the tube where the particles would strike, if they went off normal to the surface of the anode. This sun is surrounded by a halo. Third, there is less discharge from the back of the anode. Therefore, as the tendency in a vacuum tube is for the particles to collect at the anode end of the tube, giv-

[46] Opaque celluloid films are better.

ing rise to uneven pressure, this form of anode has the advantage of sending most of the anode rush toward the cathode end, thereby, perhaps, helping to equalize the pressure and being compacted, it should interfere somewhat less with the cathode stream. As a concave anode can be as easily made to rotate as though it were flat, it need not burn out any faster.

Electrical Review, February 15, 1899.

NOTE 57 — LENARD AND ROENTGEN

In Note 14, January 12, 1898, a reason why Lenard's rays were feeble was given. Other experiments and comparisons, with a study of Lenard's work, have shown the discovery of the new light was due to Lenard and not to Roentgen; that X-light was known when Roentgen took up the investigation, and should therefore have been called Lenard's light instead of unknown light. What justly brought Roentgen into such prominence was his observation that the light of Lenard would penetrate the human body. Fraught with such possibilities for good to the race, it overshadowed the primary discovery. The same thing has happened more recently with a far more interesting discovery — the so-called Zeeman effect — a change in the spectrum lines in a magnetic field. The real discoverer was Fievez. — Electrical Review, March 22, 1899.

NOTE 58 — X-LIGHT TUBE WITH BOTH TERMINALS HOLLOW

When the first efforts were made to construct efficient vacuum tubes for Dr. F. H. Williams, who has done most to prove the prime importance of Roentgen's discovery in medical diagnosis, little was known about the subject. The tubes would bear but slight force, the light in consequence being feeble. The vacuum rose rapidly until the quality of the light rendered it unfit for distinguishing between the human tissues and soon went out altogether. Attempts were made to discover principles which, when applied, should overcome these defects. The target was cooled to permit of the use of more force. Some part of the walls of the tube was made of metal, hoping to send in particles between the molecules to lower the vacuum. In these notes have been shown various ways of accomplishing these results, and some things which turned up on the way, part real and others perhaps unreal, have been mentioned; but even illusions may not be without some value, else why should Father Felician have said, "Trust to thy heart and what the world call illusions"?

As there is no end to the improvements which others will make in this field, these principles are stated again in order to prevent their being covered by a patent. Patents in medicine are unwise and should not be granted. In Plate 26, Figure 55, a reasonably powerful, simple and graceful tube constructed on the ideas mentioned is shown.

Electrical Review, March 22, 1899.

NOTE 59—INTERMOLECULAR JOURNEYS

Here is stated concisely what some who have read the previous notes have failed to understand; namely, material particles can be made by electricity to pass between the molecules of cold, dense, homogeneous metals. This is true of even the densest metals obtained for experiment. Mr. Tesla, who always sees everything in the direction he is looking, said in this journal three years ago that particles of gas from the interior of a vacuum tube passed outward through the glass. These outward journeys left the tube in too exhausted a condition to do its work. — Electrical Review, April 26, 1899.

NOTE 60 — SYMMETRY IN TUBES

In designing the aim should be to combine efficiency with beauty. As before mentioned, a regulator on the side of a vacuum tube is not pleasing. Therefore attempts were made to find better positions. Some results as applied to cooled terminal tubes have been shown. In Plate 27, Figure 56, the same plan is applied to a tube with an uncooled target. The regulator is on one end of the tube serving also as a support for the anode stem and as a place to attach a wire from the generator. Rotary target tubes are illustrated, because these are in use in a large hospital, where there is an apparatus that soon perforates a stationary uncooled target of the usual kind. It is now three years since a tube was made with a cooled target, which would bear ten times the power of the generators in use, but even at the present time there is no commercial apparatus where the power is sufficient to make them essential. No clear idea of the possibilities of this invaluable method of medical diagnosis can be formed from the results obtained with the best commercial apparatus. They give no better results in photography than the remarkable ones shown by Professor Goodspeed three years ago. We must turn to the experimental results of Tesla and Trowbridge to see what may be done. Take, for example, the fact that the latter has made a photograph of the bones of the hand in a millionth of a second. It would tax the best commercial generator to the utmost to do this in less than two million times as long. What a vista this opens! If all the power of an ordinary generator is concentrated on an oval spot on the target two millimetres long, a thin bit of platinum will stand the full force of the Crookes' stream without melting. This gives some idea of how feeble such an apparatus is. Speaking of the Crookes' stream reminds me this was discovered by Varley, who published his work in 1871. He not only observed the cathode stream, but also its effect on a pivoted mica vane. This is another illustration of what was mentioned in Note 57. But to return to the subject. Is it not singular that three years after Roentgen's discovery of the transparency of the human body to some of Lenard's rays this most important method of diagnosis should not have come into general use? Not one physician in a hundred employs it regularly, and yet with some diseases it enables the earliest diagnosis to be made. To show how important this is, take consumption, which is responsible for one-seventh of the deaths from disease. If every one would be regularly examined, a matter taking only a short time, most of the cases could be saved, for Williams has proved the signs can be detected so early, treatment is followed by prompt recovery, many cases not even requiring a change of climate. This latter is of the utmost importance, as consumption is a disease of the poor, who cannot often give up their work and go away. The fluoroscope in Dr. Williams's hands is constantly showing evidences of old tubercle scars in patients who never suspected they had been attacked by the disease. This is a point of great interest, for if in so many cases nature has unaided effected a cure, with a little help from medicine, almost every case can be saved. These details may seem out of place in a non-medical journal, but they are introduced for a purpose. Outside pressure is needed to hasten the adoption of the most important method of diagnosis discovered in a lifetime.

Electrical Review, April 26, 1899.

NOTE 61 — ON GLASS WRAPPINGS

Wrappings may have been appropriate for anything so old and dead as a mummy. For vacuum tubes, which are young and should be vigorous, they are out of place. They are fetiches worshipped long enough. With any considerable force they get knocked from their pedestals, falling down as discolored fragments in the tube. As the glass wrapping about the anode stem was the first to break, the effect of shortening the stem was tried, and finding this was an improvement, the wrapping was reduced and finally discarded entirely, as in the tube shown December 1, 1897. Next, the wrapping about the cathode stem was shortened and would have been earlier abandoned if two great experimenters, Lenard and Tesla, had not definitely stated it was of value. For some time all coverings have been given up, not only without injury to the tube, but to its distinct advantage. A tube of this kind is shown in

Plate 27, Figure 56. The method of supporting the bare stems is excellent, and when these are of large diameter, three-sixteenths of an inch, the tube will bear any reasonable amount of jar in use or transportation.

Electrical Review, April 26, 1899.

NOTE 62 — AN ELECTROLYTIC HYDROGEN VACUUM REGULATOR

Plate 27, Figure 57, shows the apparatus. It is a bit of glass tubing partly filled with acidulated water held in by the rubber cork, which serves also as the support. To charge the regulator tube with hydrogen, connect the current in such a way the gas will be liberated at the surface of the regulator tube, which should be of some metal that rapidly absorbs the gas. The device has amused me and may be of use to some one.[47] — Electrical Review, April 26, 1899.

NOTE 63 — PENETRABILITY OF X-LIGHT INFLUENCED BY TEMPERATURE

Edison and also S. P. Thompson found in 1896 the penetrability of X-light was increased by cooling the exterior of the vacuum tube. Edison surrounded the tube with oil which was placed in a freezing mixture.

These observations have been confirmed by others and have been quoted as showing the incorrectness of the fact stated in Note 30, that the wave-length of X-light depended on the temperature to which the particles of the cathode stream were raised by their impact on

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[47] Refer to Note 77; Note 80, Plate 35, Figure 68.

the target. There is, however, nothing inconsistent in these two facts. The reason why cooling the outside of the vacuum tube increases the penetrating power of the light is this, — the vacuum is kept higher, therefore the velocity of the cathode stream is greater, resuiting in shorter waves. The shorter the waves, the denser the substance they will penetrate.

How great a difference temperature makes can be easily observed by reading the gauge on the vacuum pump with the tube excited cold and again while hot. Moreover, with a focus tube it is a simple matter to show that cooling the exterior of an excited tube does not make much change in the temperature of the target against which the particles strike, and this is the place where X-light originates, and where the temperature must be altered if we wish to study its effect on the character of the light.

Electricai Review, September 20, 1899.

NOTE 64—THE EFFECT OF THE DEGREE OF THE VACUUM ON THE TEMPERATURE OF THE TARGET

One of the interesting things in connection with vacuum tubes used to produce X-light is to see, as the vacuum rises, the changes in temperature of the target where the cathode discharge strikes.

When the resistance is about equal to one-fourth of an inch of air, a powerful generator delivers so much force against the target as to quickly melt it, the platinum flying off as shooting stars of glowing metal,[48] and there is so

[48] Refer to Note 46.

much light it is easy to read ordinary print several feet from the tube.

If, however, the current is stopped in time to save the target, and pumping continued, a stage is reached where the same generator cannot make the target more than red-hot; and when the resistance is equal to 16 inches of air, it is impossible, with the same generator, to make the target even red. Yet keeping pace with this increase of vacuum, the penetrating power of the X-light rises. As the vacuum rises, a grèater proportion of the energy appears as X-light and less as ordinary light and heat. Therefore, where it is practical to use high vacuums and obtain the necessary differentiation of tissues, it is desirable to do so, on the ground of economy.

At first high vacuums in new tubes were not desirable, as they soon became too high, and useless; but with the introduction of the intermolecular vacuum regulator this difficulty was overcome.

To restate the matter in a different way, it may be said a vacuum tube is a source of heat, light and X-light, according to the degree of the vacuum and the energy of the current, and what occurs is this: as the resistance rises, the number of particles to carry the current is less, but, as the current must be carried, each particle moves with greater velocity and, striking the target with greater force, gives rise to a larger proportion of short waves, — that is, of X-light, — and a smaller proportion of longer waves, or those of ordinary light and heat.

Electrical Review, September 20, 1899.

NOTE 65 — X-LIGHT TUBES FOR ELECTROLYTIC BREAKS

When an electrolytic interrupter[49] is used to excite a single-focus tube, the definition is less perfect and the tube blackens sooner than with the usual forms of interrupters. By a single-focus tube is meant one where the anode, acting as a target, receives the discharge of a single concave-cathode, in whose focus the anode is placed, X-light originating at the small area where the cathode discharge strikes.

What causes this loss of definition? It is because a larger proportion of the particles leaving the anode have a velocity approximating that of the cathode discharge.

In other words, the alternating character is more marked, approaching more nearly to the type of discharge of a Tesla coil.

As a result, the particles forming the anode rush strike the tube in various places with sufficient force to heat the individual particles to a sufficiently high temperature to make them centres from which X-light radiates, producing in a more marked degree the phenomenon mentioned in Note 17. It follows the single-focus tube is not the best for perfect definition when the electrolytic break is employed.[50] The double-

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[49] Note added 1903. — An ordinary interrupter is used with a condenser to help the induced current to appear more unidirectional. When electrolytic interrupters are used with single-focus tubes, a series spark-gap is necessary to make the discharge through the X-light tube more unidirectional in order to avoid blackening and secondary sources of X-light.

[50] Note added 1903. — When the inverse discharge is

focus tube is a better type for this form of interrupter. There are two forms of double-focus tubes,[51] one invented by Prof. E. Thomson and the other by the writer. Professor Thomson's tube is far more economical, as it utilizes the discharge from both terminals, but having two radiant areas for X-light, the definition is less perfect than the second form. A modification of Professor Thomson's tube suitable for use with electrolytic breaks was mentioned in Note 17. In Plate 30, Figure 61, is shown the same tube in a later form. For much medical work, extreme definition is of less consequence than the amount of light. This tube is therefore an excellent type for Tesla coils and for use with electrolytic breaks. When the most perfect definition is required with Tesla coils or with electrolytic breaks at a sacrifice of some light, the tube figured in Note 16 is suitable. In Plate 28, Figure 58, accompanying this note, is shown a more recent type of the same tube, improved in mechanical construction and more efficient. In Plate 29, Figure 59, the rotary target is applied to a tube of this form. As stated in Note 16, the light from the second area or that from the back of the target is thrown out of the field, leaving but one radiant area, which being of small size may be considered as a single point from which in every direction X-light is given off. Plate 31, Figure 60, is a diagram illustrating the plan on which the tube shown in Plate 28, Figure 58, is constructed. N shows where the normal cathode stream strikes the target, giving rise to a

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controlled by series spark-gaps, the definition with suitable diaphragms is satisfactory.

[51] The double-focus tube was invented by Roentgen.

sphere of light, half of which is cut off by the platinum. Of the resulting hemisphere only a cone of X-light is used which comes through the opening in the diaphragm. This is explained in detail in Note 36. D represents the point where the abnormal stream of particles strikes the target and from which X-light also spreads as a sphere, half of which is cut off by the platinum. The resulting hemisphere cannot pass through the diaphragm, and in consequence cannot blur the definition. The drawings were made some time ago. The tubes have undergone changes since, chiefly to make it easier for the glass-blower. It remains to consider why there is increased blackening of a single-focus tube when the electrolytic interrupter is used. It is due to the greater number of particles of platinum torn off from the anode. With the double-focus tubes, both terminals being aluminum, the particles torn off from the metal and deposited on the glass do not discolor it so much. On this account also the double-focus tubes are superior where Tesla coils or electrolytic breaks are used. — Electrical Review, September 20, 1899.

NOTE 66 — THERE IS MORE LIGHT WHEN THE TARGET IS AN ANODE

Lodge showed in 1896 the X-light started from the surface struck by the cathode rays. This was the opinion of Roentgen, but Lodge added the significant statement that the rays were best when the anode was the place struck. In Note 16 it was said if a tube was arranged with the target an anode and then by simply cutting a wire, while the light was shining, was made a target only, the useful light was not sensibly diminished. Lodge was, however, correct. Various forms of tubes since made to test the matter by photography proved the exposure may be longer when the target is not an anode. The cathode stream, as shown by Varley and Crookes, is composed of material particles having charges of negative sign. When the target is an anode it attracts them as they approach it, increasing therefore their velocity. Hence the force of their impact on it is greater and the temperature to which they are raised is higher, which means, as shown in previous notes, a larger proportion of X-light to that of lower pitch. This is a point of importance in medicine, as it is desirable to shorten the duration of the exposure.

Electrical Review, October 25, 1899.[52]

NOTE 68 — OUTBURSTS OF HYDROGEN IN X-LIGHT TUBES

In Note 29 some directions were given for pumping tubes for use with generators of considerable power. Further experience in preparing tubes for still larger generators has shown many interesting phenomena, one of which, having a practical bearing, is mentioned here. In preparing a tube for such a generator it is well to make the vacuum high and also to drive out a considerable proportion of the gases contained in the glass and in the terminals. This will prevent the vacuum from falling so far when the tube is used. The ideal way is to

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[52] Notes 14, 15, 16, 31, should be read, as they describe tubes with three terminals and explain some of the advantages of this construction.

have the pump arranged to exhaust the tube while it is lighted by the same generator on which it will be afterward used. Every hospital should therefore have a portable pumping plant for this purpose.[53] Until such an arrangement is commercially available this method is practical only for experimenters. In consequence, a tube requires a considerable period of readjustment before reaching maximum efficiency when used on a more powerful generator than the one employed to light it while being pumped. If such a tube is observed when the current is first sent through it by the more powerful generator, the amount of light and definition are both unsatisfactory, for the cathode stream is not normal. The energy being greater appears to have difficulty in escaping from the concave surface of the cathode, because the gas has been more thoroughly removed from the metal here than from the back. As a result, there are constant irregular outbursts of hydrogen from the metal at the back of the cathode. The velocity of these particles is great enough for them to radiate X-light when they strike the glass walls of the tube. Their impacts also show as vivid green patches on the glass. If the tube is kept lighted, these appearances stop, the cathode stream becoming normal. Most of the power being now delivered in the normal stream on the radiant area of the target, the amount of available X-light increases and the definition improves. Continued observations show a considerable proportion at least of the particles, whose impacts on the target cause

[53] Refer to Note 173, containing an illustrated description of a suitable apparatus.

X-light, come from the metal of the cathode, and are not those in circulation in the tube. The cathode is, therefore, not only a muzzle-loading gun, but also a magazine arm highly charged with hydrogen bullets.

Electrical Review, November 1, 1899.

NOTE 69 — A TARGET-ANODE WITH A SLIT

At first the air was full of theories of X-light. One was, the rays were streams of particles moving in straight lines; in other words, real rays instead of waves. In thinking of experiments to test the various theories, a number of tubes were made, one of which is shown in Plate 32, Figure 62. To avoid the diffusion which Lenard had observed when the rays were sent through air, they were transmitted in the same vacuum in which they were generated. In the tube shown, the target-anode is placed perpendicularly to the line of the cathode stem. The central portions of the Varley stream therefore strike its surface perpendicularly, those forming the outer portions at a small angle. If the target presented a smooth surface to these particles, the result of this construction would be to concentrate them more than when the target was placed at the usual angle of forty-five degrees, increasing the collisions: but as these particles are small and the surface relatively rough, this construction does not much increase the light yielded by a tube. In the tube figured the radiant area caused by the impact of the Varley stream is shown by the spot where the line extending from the letter R strikes the target; while as close as possible to this area is a slit made by riveting another piece of platinum to the target. The width of this slit is one one-hundredth of an inch; its length in the direction the rays must pass through it is half an inch. The object of placing the slit on the target was to have it as near the place of maximum brilliancy as possible. The rays in passing through the slit went forward in the direction shown by the diverging dotted lines to B. When a fluoroscope or a photographic plate was placed against the tube at this point, the band of light was wider than it should have been if the rays were streams of material particles moving in straight lines.[54] — Electrical Review, November 1, 1899.

NOTE 70 — AN X-LIGHT TUBE THAT WAS A BELL

In Plate 33, Figure 63, is shown a tube in which the only support for the cathode stem is a hollow platinum regulator sealed to the glass. As a result, the cathode can vibrate slightly in the direction of the dotted arc, but not enough to touch the walls of the tube. The tube was exhausted to a high vacuum while lighted and hot. When cold the resistance was so high the Varley stream had difficulty in starting. As a result, there was the lateral sparking described in a previous note. Shortly the cathode began to vibrate. If the hand was placed on the bulb

[54] Note added 1901. — This only applies to uncharged particles. Charged particles would spread, as stated in Note 3. Refer to Note 109 A for an experiment showing that X-light is not a flight of particles either charged or uncharged. Refer also to Note 133 on an aluminum condenser.

between the terminals, the Varley stream would start and the vibration stop. If the stem was grasped behind the cathode disk, the Varley stream did not form, and the tube could be felt in vibration. The cause of the phenomenon was this: The cathode, being capable of some vibration, was pushed by the particles shot off from its edges, there being a mutual repulsion due to their charges being of like sign. When the vibration became rhythmic, the particles striking the glass in regular surges caused it to ring like a bell, though struck by nothing larger than a molecule. The ringing could be heard forty feet away. — Electrical Review, November 1, 1899.

NOTE 71 — GROUNDING THE ANODE OR THE TARGET

Many operators ground the anode, as it is supposed to prevent burning the patients. The following experiment proves it diminishes the light. Take the tube shown in Plate 6, Figure 2, or the one in Plate 29, Figure 59, and connect the target, which is at the same time an anode, with the ground by a fine wire, which can be removed without jar while the observer is looking in the fluoroscope. The moment the connection with the ground is severed the light increases. If one of the concave aluminum terminals is an anode and the platinum plate only a grounded target, on repeating the experiment the same result will be obtained.

Electrical Review, November 8, 1899.

NOTE 72 — THE POWER OF HARMONICS

A tube like the one shown in Plate 27, Figure 56, Note 60, was attached to the generator mentioned in Note 67. The spark-gap in shunt was opened to fifteen inches, but no discharge went through the tube. Two multiple spark-gaps were then placed in series with the tube, one on each end. Holding the cords controlling these in the hands, they were adjusted until a rate of surging was found which caused the tube to light up. As soon as this occurred, the spark-gap in shunt was reduced without the current crossing, showing the resistance of the tube was less. Why did the multiple spark-gaps cause the tube to generate X-light? This was the reason. The tube had been pumped to a high vacuum to fit it to a powerful generator. It had been used in a large hospital until the generator could not light it. Evidently all the hydrogen in the cathode, which was not firmly held by the aluminum, had been driven out by long use, until an electric pressure sufficient to cause a spark to jump fifteen inches of air had no power to send out more. By running down and up the scale of the electric surges, an harmonic of the hydrogen particles was found, — which therefore were thrown into stronger and stronger vibration until escaping from the attraction of the aluminum particles they rushed out striking the target with a high velocity and producing X-light of great penetrating power, for we could see our hearts at a distance of thirty feet from the tube. After observing the tube for half an hour the spark-gaps in series were closed. The spark-gap in shunt was reduced to measure the resistance of the tube, which was found to be less than a tenth of an inch. The color was deep blue, the Varley stream and the target reflection both white and there was no X-light. This showed the short period of running had forced a great number of particles into the circulation. The experiment also proved the importance of the statement made in Note 39, that a high potential was desirable in a generator for lighting X-light tubes. — Electrical Review, November 8, 1899.

NOTE 73 — MASSIVE CATHODES

Until these experiments introduced a different type, the object of tube-makers was to have the tubes as small as possible and with very light terminals. The anode was made of a small piece of platinum foil, and the cathode of a small and thin disk of aluminum supported by so slight a stem as to require a glass support. In Plate 7, Figure C, Note 19, was shown a massive cathode, and in later notes strong tubes properly proportioned to bear the force from powerful generators, and with cathodes of sufficient mass to serve as reservoirs of hydrogen. These are matters of practical importance in hospital work, where the tubes are often kept lighted for many hours in a day. Under these conditions a light cathode would soon show signs of exhaustion. With massive cathodes a tube has frequently been kept lighted by a powerful generator without any signs of fatigue appearing after ten hours' run.

Electrical Review, November 8, 1899.

NOTE 74 — X-LIGHT A HYDROGEN PHENOMENON

Scattered through these notes are various experiments and statements showing how X-light is produced. Briefly, this is the way: Particles of hydrogen come rushing out of the cathode, strike against the target, are heated, and vibrate, throwing the ether into waves unlike those of ordinary light, because of higher pitch and shorter trains quickly diminishing in frequency and amplitude, as the particles being small lose heat rapidly. Few accept this theory, therefore some simple experiments will be mentioned, which those who hold other theories may consider.

Place a tube on the pump and exhaust it until it produces no X-light. Then consider some of the ether theories, which are that cathode and X-rays are portions of the ether, either of the vortex ring or other type, coming from the cathode. An experiment was mentioned in Note 69 which was against these theories, as it appeared to indicate X-light penetrated into the geometrical shadow. In the present experiment consider in what way the cathode has been changed when X-light is no longer produced. If X-rays were portions of the ether shot out from the cathode and there came a time when there were no more X-rays, we should be justified in thinking the amount of ether in the cathode had been diminished. Also, if the experiment showed ether had been driven out of the cathode, the only thing required for the production of X-rays again would be rest, to allow the ether to go back, but such a tube could rest until doomsday and not make the faintest spark in the universal gloom. Not feeling competent to achieve such a wonderful result, it seemed probable what had been done was only to reduce the supply of hydrogen in the cathode until a condition of equilibrium had been reached between the electric stress and the attraction of the remaining hydrogen for the aluminum. Therefore rest alone should not enable a tube to generate X-light again, but fresh supplies of hydrogen should produce this result, and it was only necessary to use the electrolytic regulator figured in Note 62 to get brilliant X-light.— Electrical Review, December 6, 1899.

NOTE 75 — DEPTH OF THE RADIANT AREA

In Note 69, Plate 32, Figure 62, was shown a target-anode with a slit. Here consider an experiment with a similar slit which is raised a hundredth of an inch above the plane of the target, with the nearest opening one-half inch back from the edge of the raised piece. Excite the tube and look at the image made by the X-light coming through the slit. Then consider the theories of Stokes and J. J. Thomson, which fortunately are now easily accessible, having been reprinted in Roentgen Rays by G. F. Barker. Stokes says: "Well, then, this is what I consider to constitute X-rays. You have a rain of molecules coming from the electrically charged cathode, which you may think of as so many rain-drops in a shower. They strike successively on the target, each molecule striking the target producing a pulse, as I have called it, in the ether, which is essentially partly positive and partly negative. The simplest form of pulse, as I call it, in order to distinguish it from a periodic undulation, would be one consisting of two halves, in which the disturbances were in opposite directions. The positive parts are not necessarily alike, as one may make up by a greater width measured in the direction of propagation for a smaller amplitude, it will be simplest to think of them as alike."

Thomson says: "Thus we see that the stoppage of a charged particle will give rise to very thin pulses of intense magnetic force and electric intensity. Two pulses are started when it is stopped. One of these is a thin sheet, whose thickness is equal to the diameter of the charged particle; this wave is propagated in the direction in which the particle was moving; the other is a spherical pulse, spreading outward in all directions, whose thickness is again equal to the diameter of the charged particle. The theory which I wish to put forward is that X-rays are these thin pulses of electric and magnetic disturbance which are started when the small, negatively charged particles which constitute the cathode rays are stopped." According to Kelvin, the diameter of a hydrogen particle is in the neighborhood of one ten-millionth of a centimetre; therefore the magnitude of the vibration which would be started in the ether on these theories would not be greater than this measure. To such a dimension the one-hundredth of an inch of platinum, on top of which is the slit, would be a vast cliff in whose shadow the slit would be quietly reposing, lighted but dimly, for no portion of the direct rays from the radiant area far below could enter it fairly; because, according to these theories, the depth of the radiant area at the base of the platinum cliff is only about the diameter of a hydrogen particle. But the slit was so brightly lighted diffraction fringes were obtained in half an hour's exposure, and a bright image on the fluoroscope at a distance of two feet, so my earlier explanation, that the particles of the cathode stream are heated to a very high temperature by their impact on the target, is better. As it takes time for the heat to decline, the particles retain a sufficient temperature, when they have rebounded to the opening of the slit, to make them still centres from which the ether waves we know as X-light originate, therefore, as the wave-fronts can enter the slit directly, this is brilliantly illuminated.

Electrical Review, December 6, 1899.

NOTE 76—THE PRODUCTION OF A VACUUM IN AN X-LIGHT TUBE

Those who have had experience with X-light tubes excited by powerful generators have observed, among others, the following phenomena: When they purchased a tube without an automatic regulator from the makers and excited it, the vacuum would fall until a long spark-gap in series had to be used to make it produce X-light, or perhaps it fell so far that the tube had to be returned. The stress drove gas into the tube. After repumping, it will stand up better, and when it has been run a long time the opposite effect appears; namely, the vacuum is so high heat must be used before starting the tube to avoid punctures. Then, after more use, a stage is reached when heat is not effectual. Next, the potash bulb is heated. After a time this method also fails satisfactorily to lower the resistance. Then the tube is sent to be repumped. After that it will run for a while, but the appearances are different. The vacuum may be lowered again with potash, but there is less X-light and the color of the glass is dull. The tube may be again repumped, but never is it as good as a new tube. What is the reason? It is this: Hydrogen is practically exhausted from the cathode. No more can be sent out except under greater stress from a more powerful generator, and if so sent out and X-light generated it will go back. Then the smaller generator cannot light the tube. The following experiment proves this. Put a new tube on the pump and exhaust it hot while lighted, until no X-light is given off. Then by harmonic vibrations start the cathode stream and maintain it as long as possible, continuing the pumping until the light dies out. Now introduce any of the ordinary gases except hydrogen and lower the vacuum. You can then start the cathode stream and get a little light. Continue the pumping until the light fades and introduce more gas. In this way the same result is reached in a few hours that is obtained in practice by long use. The tube is old and dull. Now introduce hydrogen by the electrolytic regulator, which can be done for an hour without appearing to lower the vacuum much, for the gas is absorbed by the cathode. This can be proved in the following way: As soon as enough has gone in to enable the cathode stream to start, keep the tube lighted; that is, keep the cathode expiring hydrogen so this hydra-mouthed monster cannot swallow the fresh supplies. Then it will be seen the vacuum is falling. It will come down to a lovely rose-pink mixed with blue. After a time the tube can give as brilliant results as a new one. This experiment would therefore appear to show hydrogen[55] was needed to make

[55] The metallic sodium in the tube must be heated when hydrogen is being studied, otherwise water vapor will mask the results.

new lamps from old ones, though for practical purposes a pure hydrogen vacuum may not be as good as some other kind, as the following experiment indicates: Exhaust a tube as above until it reaches old age, introduce hydrogen until the light is brilliant, keep the tube lighted and on the pump. Practically the only gas in the tube is hydrogen, as the other gases are pumped out after a time. Such a tube is not practical for all generators, because the vacuum when cold goes up too high to start easily [56] on a small generator, for the hydrogen is absorbed when the tube is at rest; or if a greater amount of hydrogen is in the cathode, so the tube starts easily, then it quickly runs down in use until it requires long spark-gaps in series to make the hydrogen strike the target with a sufficient velocity to produce X-light. What we want is some stable gas which will not be readily absorbed to form a groundwork vacuum. We are accustomed to think of nitrogen as an inert gas, yet under these conditions it was anything but stable, nor was carbonic anhydride permanent. Oxygen was very interesting, but not perfectly satisfactory. Some oxygen phenomena are mentioned. A tube was made with a regulator, as shown in Note 50, Plate 25, Figure 52, which allowed either hydrogen or oxygen to be introduced. The tube was pumped while excited until extreme old age came on. Oxygen was then repeatedly introduced until the vacuum was supposed to be mostly of this gas. The tube was excited and a stream of hydrogen sent in. After an hour the vacuum was no lower. What had become of the hydrogen? It

[56] This refers to tubes without automatic regulators.

had not gone into the cathode, for this was sending out gas. We are accustomed to think of the union of hydrogen and oxygen as one of explosive violence. For some time what was happening was not understood; but a little heat applied to the glass told the story, for the vacuum went down with a rush. Here then was this exothermic reaction going on under the electric spark quietly. No permanent gas was found perfectly suited for a ground vacuum, and having learned by experience how hard it was in spectrum analysis to get rid of water vapor, it seemed a pity to part such good friends as glass and water, therefore an attempt was made to find some practical use for their affinity. The experiment was successful. Therefore two regulators may be put on one tube, one to introduce hydrogen, and the other water vapor or oxygen.[57]

Electrical Review, December 13, 1899.

NOTE 77 — PALLADIUM INTERMOLECULAR VACUUM REGULATOR

In previous notes various ways of regulating the vacuum have been mentioned, and in Plate 27, Note 62, Figure 57, the electrolytic regulator was shown. Between having a device satisfactory for demonstrating a principle, and making it cheap enough to be commercially available, there is frequently a long road. Some time has been spent in making this regulator in a cheap form. Seamless platinum tubing was obtained from Baker, with a bore of one fifty-thousandth of an inch and walls fifteen one-thousandths of an inch thick, in pieces one inch

[57] Refer to Note 50 for a figure of a regulator of this kind.

long. One end of a piece was closed with a palladium tube three one-thousandths of an inch thick, soldered on with gold. In this form the regulator is cheaper than my platinum heat regulator, for this tube must be two and one-half inches long, and even then the glass will crack unless some care is used. If the short piece of tube after attachment to the vacuum tube is placed in the feeder, shown in Plate 27, Figure 57, and this filled with water, it is only necessary to send a current of sufficient strength through the water to decompose it, to cause hydrogen to go either in or out of the tube according to whether the palladium is the positive or negative pole. If there is an Edison 110-volt current near, the simplest way is to connect cords with a lamp socket putting two sixteen candle lamps in series, one on each wire, leading the wires to the feeder.[58] If the street current is not available, a few dry cells in a portable box answer every purpose.

Electrical Review, December 13, 1899.

NOTE 79—CHEMICAL HYDROGEN REGULATORS FOR CHEAP X-LIGHT TUBES

It is possible to buy an X-light tube for five dollars, which leaves the makers so small a profit they must economize on platinum. They are, therefore, unable to use intermolecular regulators of platinum or palladium, and either have none or the potash or the oxygen bulb. My tube-makers two years ago were given a formula for a chemical regulator which liberated hydrogen, but as their work is chiefly in furnish-

[58] Refer to Note A.

ing the finest tubes to hospitals, they have little use for it. The method is now published, as worthy of extended use in connection with low-cost tubes, for it increases their price only five cents. What is necessary to revive cheap tubes is to have some chemical in a small supplementary bulb which will liberate hydrogen at a temperature below the softening stage of glass. Sodium formate will do this.

Electrical Review, December 20, 1899.

NOTE 80 — SUPPORTING THE STEMS OF X-LIGHT TUBES

In Note 61 it was said the universally used glass wrappings about the stems of the terminals in a vacuum tube were not only unnecessary but undesirable. In Plate 27, Figure 56, a tube was shown with strong bare stems supported by diaphragms blown in the glass. As we should aim to make a tube which will be easy to construct, while durable, graceful and efficient, this kind of support should be abandoned, for it needs a good workman to make it, and sometimes the glass will crack at the seal. The stems are now supported by collars. This construction applied to rotary and cooled target tubes is shown in Plate 34, Figures 64, 65. In these illustrations the electrolytic regulators form the support for the cathode stems, thus doing away with one piece of platinum wire. This position for the platinum heat regulator has been employed for a long time, but on account of the length of the platinum, it has been criticised as making the vacuum tube more liable to injury than when the regulator is placed on the side. The electrolytic regulator is now so short this objection is without force. Plate 35, Figure 68, shows the detail of such a regulator. — Electrical Review, December 20, 1899.

NOTE 82 — APPEARANCES OF PERFORATED TERMINALS IN VACUUM TUBES

In previous notes perforated terminals were mentioned. The appearances seen with these were observed by Goldstein, but remained unexplained. The following statement is therefore given: The particles of hydrogen being shot off perpendicularly from the sides of the openings, approach each other, but having charges of like sign are mutually repelled, the curve of motion being a resultant of these two forces. Usually the phenomena take the appearance of somewhat pointed flames. That they stream backward from a concave cathode is but natural.

Electrical Review, January 10, 1900.

NOTE 83 — HYDROGEN IN METALS

Cathodes were made of most of the common metals to study their behavior under electric stress. Hydrogen was found in most. In zinc, for example, it is so abundant and amalgamated in such a way this metal makes a good cathode so far as the production of X-light goes. In those metals which are solids at ordinary temperatures and where it is not abundantly present, the cathodes are likely to melt suddenly when much stress is used. This is an interesting illustration of the direct conversion of electricity into heat. The electricity does not escape, for there are only the particles of the metal to carry it, and these being heavy are not so efficient as the light particles of hydrogen. — Electrical Review, January 10, 1900.

NOTE 84—REDUCING THE COST OF X-LIGHT TUBES

It would be pleasant to see every physician use X-light. To hasten the coming of this happy day it is necessary to make the tubes cheap, as well as durable, efficient and graceful. In this note, some attempts, though not the most recent, are mentioned. The tube shown in Plate 35, Figure 69, is made from one piece of glass. As the bare stems of the terminals balance on the disks when sealing in, their weight does not cause them to drag on the soft, hot glass. The operation is in consequence a simple one which may be done by cheap labor. If the tube is provided with a rotary target and an electrolytic or chemical hydrogen regulator, it will last for a long time. When blackened, perforated or broken, it is a simple matter to remove the terminals after soaking them in hydrogen, putting them into a new tube which need not be expensive, for one company says it will make bulbs like Plate 36, Figure 70, for fifty cents. It is a simple matter to cut off the ends as in Plate 36, Figure 71, sealing in the old terminals, thus making almost a new tube. This is a point of practical importance, as a blackened bulb makes the action of a tube irregular by absorbing and giving off gas, and the metal acting as a conductor diverts part of the current, diminishing the efficiency. In the ideal tube the energy is concentrated in the cathode discharge and delivered on a small area of the target.

Electrical Review, January 10, 1900.

NOTE 85 — MERCURY CATHODES — THE FREE ELECTRON AND OTHER ETHER THEORIES OF CATHODE RAYS

One of the most beautiful pieces of quantitative work on cathode rays is J. J. Thomson's determination of the charge on the particles. He found this to be 10^{-3} of that of the hydrogen atom in electrolysis, concluding in consequence that the cathode stream was made of ultimate corpuscles. Most of us would have been content with having reduced the idea of mass to such small units, but not so Sutherland. In the Philosophical Magazine for March he dismissed all idea of mass, saying free electrons appeared in the ether, forming the cathode stream, the presence of ions being incidental only. He defined a free electron as a spherical shell of electricity. As stated in previous notes, cathodes were made of all the common metals, among others of mercury. After my attention had been called to Sutherland's theory one experiment with a mercury cathode was repeated. A tube was made like that shown in Plate 37, Figure 72, and attached to the pump in a position to leave both terminals, which were of platinum, uncovered as at A. It was exhausted until the X-light was brilliant. By bending the stem as indicated by the dotted lines, the tube was brought into position B, the fluid metal covering the platinum cathode. The tube then had a mercury cathode. On exciting it again, the light, though bright, would not show the bones of the hand — because the waves were too long not to suffer diffusion in the tissues. Not being a physicist, theories were only "considerations by the way" while attempting to make a cheap and efficient X-light tube to be used in medicine. Therefore none of the ether theories of cathode rays are criticised, the experiment being mentioned, hoping those who believe in these theories may explain why there was no X-light with a mercury cathode, for surely the ether is present in mercury as well as elsewhere; at least, there is no experiment which disproves this. By bringing the tube back to the original position, the X-light flashed out again. The following explanation is suggested, as it appeared to be confirmed by work with a Rowland concave grating. One reason why a mercury cathode is not efficient is because this metal does not contain enough hydrogen. The current is therefore carried by the metal, which on account of its weight[59] does not strike the target with sufficient force to heat the particles to the high temperature required to make them radiant centres for X-light. When the platinum was uncovered again, hydrogen came rushing out, producing the usual phenomena. When, on account of expense, a careful selection must be made from the wilderness of possible experiments suggesting themselves, it is always pleasant to have a simple and cheap experiment suggest in what direction future useful work may be done, because I do not love knowledge for its own sake, striving to know the mysteries, that others may use them to diminish the suffering in this sad world of ours.

Electrical Review, January 17, 1900.

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[59] The large amount of mercury carried in the cathode stream per minute indicates that the cathode stream is often composed of particles much larger than the usual estimates. Only a few minutes are required to make a bright mirror of the X-light tube from the mercury depos-

NOTE 86—THE CHARGE ON THE PARTICLES OF THE CATHODE STREAM

One charm of a theory is the excuse it gives for trying an experiment. Though the theory may not be proved, the beauty of the scene is sufficient compensation. An interesting theory is that the velocity of the particles of the cathode stream is the same for all gases. A few simple experiments show the observations which were supposed to prove this theory may be otherwise explained so far as they apply to X-light tubes by saying that at the degree of vacuum used for X-light the charges in the cathode stream are carried by hydrogen, whatever the nature of the gas with which the tube is supposed to be filled. In connection with the idea of a constant relation between mass and charge, which is a part of the theory mentioned, an experiment is described. Pump an X-light tube such as is shown in Plate 34, Figure 65, until using the full force of the generator it gives brilliant X-light. Then introduce hydrogen through the electrolytic regulator shown in Plate 34, Figure 65, and in detail in Plate 35, Figure 68. Continue the pumping until the vacuum is practically all hydrogen.[60] Stop the pump when the fluorescent screen is bright, and the bones of the hand only faintly visible. In this condition the ether waves called X-light are the longest which will pass through the flesh without suffering diffusion as do those of ordinary light. Ac-

ited over the interior surface of the glass of the bulb. The same phenomenon occurs rapidly with a palladium cathode when the gases have been removed from the metal.

[60] The metallic sodium in the tube should be heated to remove water vapor.

cording to the theory advocated in these notes there is then an amount of charge on the particles of the cathode stream which causes them to travel with a certain speed to be called unit velocity for the production of X-light. Next, continue the pumping until the image of the hand is brighter, the image of the bones relatively brighter, with their structure sharply defined. This changed appearance is not due to more force being sent through the tube, for the full force of the generator was used in the first instance, but is due to the way the force is expended. In earlier notes this was explained by saying the velocity of impact was now greater because the charge on the particles was higher, in consequence the temperature of the particles was higher and the resulting ether waves shorter. This and other experiments suggest that before the theory of a constant relation between mass and charge can be said to be established, it should explain these phenomena. The word particle has been used in these notes instead of molecule, ion, atom, hyperatom, neutron or electron, for it serves as a symbol to fix the attention without committing us to any theory as to the ultimate nature of mass or charge.

Electrical Review, February 7, 1900.

NOTE 87 — ON THE FATE OF GAS IN X-LIGHT TUBES

When an X-light tube has been run a long time, the walls are dark with various colors, alluded to in previous notes. Through the courtesy of the tube-makers considerable amounts of this glass from old tubes were collected. Part of the color could be removed by chemical means, analysis showing it was due to deposits of metals, varying with the nature of the terminals. Where glass wrappings had been used, that had broken and discolored, lead was also present. After treating the glass with aqua regia to remove the metals, there remained a purple color not affected by chemicals. This resembled that in some of the south windows in a few of the old houses on Beacon Street, in Boston.[61] When these purple fragments were heated the color disappeared, the glass being restored to its natural color; hydrogen appearing in the apparatus, as shown by its spectrum. Therefore, the gas was not simply occluded, but had chemically combined with the glass under electric stress, affecting the manganese.

Electrical Review, April 11, 1900.

NOTE 88 — ON HEATING X-LIGHT TUBES HAVING HIGH RESISTANCE

In the first two months of X-light the resistance of tubes was lowered by heating the bulbs. This was abandoned, because after a time it became inoperative. Experience extending over several years has, however, shown what is required is simply more heat. One reason for this was mentioned in Note 87. The heat liberated gas in chemical combination with the glass with which it had united under electric stress. A convenient heater can be quickly made from the oven of a gas stove, the centres of the iron ends being replaced by asbestos, through which go the terminal wires to the

[61] The same color is produced in glass outside the tube, as it appeared in the glass diaphragm shown in the figure in Note 36; therefore it is also produced by other causes.

tube. A glass door and a thermometer are convenient. There should be a small hole opposite the anode to enable the effect of the heat to be observed. With the intermolecular regulator described in previous notes, any degree of heat the glass will bear can be used, but with chemical regulators of oxygen or hydrogen, the end bearing the regulator must be outside the oven or the heat will liberate the gas from them.

Electrical Review, April 11, 1900.

NOTE 89 — THE RESISTANCE OF A TUBE IS NOT AN INDICATION OF THE DEGREE OF THE VACUUM

The terms "hard and soft" or "high and low" vacuum should not be applied to X-light tubes. The "resistance" is a better term. In previous notes it was shown this varied with the nature of the gas, the kind of terminals, and the form of the tube. Nor is the wave-length of the light necessarily dependent upon the degree of the vacuum. A tube having much water vapor, for example, may with a high vacuum give the same kind of light though in less degree as a lower vacuum tube, with pure hydrogen. In fact, it is possible to have a tube on the pump show brilliant light of any desired quality, and in a short time entirely change all the appearances by changing the gas; yet the pump gauge can be made to indicate the same degree of vacuum.[62] The experiment of the mercury cathode described in Note 85 should be considered in this connection.

Electrical Review, April 11, 1900.

[62] Further experience has proven pump gauges to be unreliable.

NOTE 90—TREATING THE ELECTROLYTIC REGULATOR AS A STOREHOUSE OF HYDROGEN

Instead of placing the palladium tube in water, after the palladium has become charged by the first treatment, heat may be used to liberate the stored gas in the metal. A simple way to do this is to make a heater of a coil of platinum wire to slip over the regulator tube shown in Plate 35, Figure 68, Note 80. Care should be used not to have too much heat; a low temperature is sufficient. — Electrical Review, April 11, 1900.

NOTE 91—THE PHOSPHORESCENCE OF THE GLASS OF X-LIGHT TUBES

Observers have said the phosphorescence of the glass was not connected with the production of X-light, which might be brilliant when there was no phosphorescence. For practical purposes tube-makers may be sure, however, that a tube made of any of the ordinary kinds of glass should not be taken from the pump unless it glows with a brilliant white light after the current has been cut off; for this brilliant phosphorescence is always present in a fine tube, and if it is absent the tube will not give satisfaction. — Electrical Review, April 11, 1900.

NOTE 92—THE RADIANT AREA PLUME

Make a tube like the one shown in Plate 34, Figure 64, Note 80, with these dimensions: Radius of cathode curve, thirty-five and a-half millimetres; diameter of cathode, thirty-five and a-half millimetres; distance of the target, seventy-one millimetres; diameter of the target, twenty-eight millimetres; angle, fifty-six degrees. Exhaust to a good X-light vacuum. Excite it on a powerful static machine such as has been described in these notes. Lower the vacuum temporarily by heat, until the anode glow covers the face of the target. Adjust the spark-gaps in series, until a pale blue plume starts from the radiant area on the target where the cathode stream strikes it -Note 28-. This will curve forward toward the cathode, striking the glass at the point marked corona in Plate 24, Figure 51, Note 49. Turn the face of the target toward the observer. Mount a powerful magnet to rotate in a vertical or horizontal plane, and to slide in a horizontal one. Place it, with its long axis in a horizontal plane, at right angles with the tube, in the same horizontal plane as the target. Turn it to bring austral[63] magnetism nearest the target. Slide the magnet toward the target. The radiant area plume will be repelled, moving clockwise on the face of the target. Withdraw the magnet. Turn it until boreal magnetism is nearest the target. Approach the magnet to the target. The radiant area plume will again be repelled, turning contra-clockwise on the face of the target. Rotate the magnet through a vertical plane. The radiant area plume will continue to revolve on the face of the target as long as the magnet is in motion. Allow the tube to cool. As the resistance rises the plume straightens, striking the glass wall of the tube at a point nearer the target. The plume is curved because some of the particles of which it is composed are at-

[63] The terms austral and boreal are taken from Maxwell.

tracted by the cathode. It straightens as the resistance rises, because these particles under these conditions, moving with a higher velocity, are less subject to outside attractions. Where it strikes the glass it spreads like the top of a waterspout. This will be considered in connection with the appearances mentioned in Note 69, if photographs can be made of sufficient intensity to reproduce. — Electrical Review, April 11, 1900.

NOTE 93 — THE FAN OF THE VARLEY STREAM

Use the tube mentioned in Note 92, adjusting the temperature until the Varley stream appears as a pale blue cone, with its apex on the target. Place the magnet mentioned in Note 92 in the same horizontal plane as the target, which is to face the observer. Have the magnet so near that it displaces the apex of the Varley stream until it stands clear of the target. Have the magnet turn in a vertical plane and revolve it. As it turns, the Varley stream also turns. Place the magnet with austral magnetism to the observer's right. The fan is then on the opposite wall of the tube and spread through a vertical plane. When boreal magnetism is to the right, then the fan is on the wall nearest the magnet and spread in a horizontal plane. As the magnet rotates, the fan spreads in intermediate planes as it revolves about the tube. The fan is easily seen, not only on account of its color, but because of the brilliant green figure it makes where the particles strike the glass.

Electrical Review, April 11, 1900.

NOTE 94 — NON-RADIABLE CASES FOR X-LIGHT TUBES

An X-light tube fills a room with a bright light which blurs the image on the fluorescent screen and fogs a photographic plate, though it be in a non-radiable case, open only on the side opposite to the tube. Therefore, in using this light for medical diagnosis, the tube should be placed in a non-radiable box, out of which no light can escape except the smallest cone of rays which will cover the area to be examined. A simple experiment is to use a tube powerful enough to obliterate all details in the chest. By enclosing the tube, the heart, lungs and ribs appear plainly, without in any way altering the nature or intensity of the light. There is, however, another way in which injurious diffusion shows itself in looking through the deeper parts of the body even with an enclosed tube. To illustrate this, hold a piece of glass two centimetres thick between the hand and the tube. The image of the hand appears on the fluoroscope, but detail is lost. This diffusion is also made less by the procedure recommended.

A simple tube-holder is shown in Plate 38, Figure 73. The tube box -E- of wood is coated on the inside with white lead one millimetre or more thick. As lead oxide ground in japan dries in an hour, the requisite thickness can be obtained in a day. The revolving diaphragm block, also of wood, is recessed at the back and lined in the same way. The tube box moves on the hollow standard -A- on ball-bearings. Inside the standard there is a weight, which, balancing the box and its contents, enables the tube to be quickly moved into position above, below or at the side of a standing, sitting or reclining patient. The tube box is movable through a vertical arc about the pivot. H is a sliding frame for the grounding screen Q. M is a water can for the cooling water for the hollow target tube shown in Note 1, December 1, 1897. By means of the support N and the clamp O, the can may be placed at any desired level. The distance of the tube from the standard A is regulated by the sliding rod moving in the socket K. Photographs are constantly seen which might have been better if such an arrangement had been used, and a non-radiable covering[64] placed about the patient, open only to allow the necessary cone of rays to pass. Without such appliances it is impossible to obtain the best results in photographing the deeper portions of the body.[65]

Electrical Review, April 11, 1900.

NOTE 95 — TWIN X-LIGHT TUBES[66]

In previous notes the following statements were made: The degree of the vacuum is not an index of the resistance of an X-light tube, — Notes 30, 53, 89. The cathode is not only a muzzle-loading, but also a rapid-fire magazine gun, — Note 68. Of the gas shot out from the

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[64] Refer to Note 174 for formula for the non-radiable paint.

[65] Consult Notes 36, 139, 143, 144, 149.

[66] This experiment has been criticised because the connecting tube was so small as to prevent the vacuum being the same in both tubes. Refer therefore to the tube shown in Note 103, which has two cathodes in one bulb. The same phenomena can be produced with it.

terminals part will return and some will go into the walls of the tube. Of the latter, a portion combines with the glass, giving it a purple tint, which can be removed by heat, the gas appearing in the tube again, — Notes 76, 77. Some of these facts may be studied by the aid of the simple tube shown in Plate 39, Figure 74. The tube is composed of two like bulbs blown from the same piece of tube at the same time. The metals for the terminals were cut from the same plates and rods, and are exactly alike. The targets were at the same distance. As the two bulbs composed a single air system, there was the same vacuum in each, when in repose. When subjected to the same treatment, the amount and character of X-light was the same in each. Bulb A was then treated to greatly increase its resistance. Bulb B was prepared for yielding good X-light. When excited the resistance was equal to ten centimetres of dry air. The terminals of the same Ritchie coil -twelve-inch- were then attached to the loops of bulb A. The resistance was equal to twenty centimetres of dry air. In other words, while the vacuum was the same, the resistance of one bulb was at least twice as great as the other. What caused this difference, which could be and was easily made greater ? Chiefly this, — in one bulb the terminals had been made more free from gas. Bulb B was next excited for a considerable time, the equivalent air resistance falling to five centimetres. The terminals from the coil were then attached to bulb A. The resistance in it had fallen to ten centimetres of dry air. What had happened ? Some of the gas from the terminals of bulb B had taken advantage of the opportunity and had gone into the terminals of bulb A. Bulb A was then continued in an excited state for a long time, the resistance rising gradually to twenty centimetres again. What caused this rise when the vacuum was not rising? This, — the gas was again being forced from the terminals, and the current found less on which to ride that part of the field between the fronts of the terminals. Now bulb A was heated, lowering the vacuum and the resistance. Then the other with the same result. What had lowered the vacuum? Gas, mostly hydrogen, from the glass. What had lowered the resistance? There were more particles in circulation to carry the current, which now depended less upon the particles in the metal on which to ride across the field. As the vacuum was the same in these bulbs when at rest and practically the same for a few moments after the current started, the character of the light should have been the same, if it depended upon the degree of the vacuum simply. Evidently then, as stated in Notes 3, 6, 18, this is but one factor, for in one bulb there could be the kind of light which made the bones as light as the flesh and in the other a light which gave great contrasts between them. What made this difference in the same vacuum? The charges on the particles of the Varley cathode stream were greater in one case, causing them to strike the target at a higher velocity. What caused the greater charge on the particles? The greater attraction between the gas and the metal. How does really lowering the degree of a vacuum affect the character of the X-light? By sending more particles into the circulation, the flying particles from the cathode meet with more obstruction on their way to the target, and the initial charge on each is lowered, because there are more to carry the amount of current, which therefore depends less upon the particles from the metal on which to ride the field. With the tube shown it was a simple matter to exhaust one cathode until there was almost no X-light, because only a fraction of the current rode the field in the direct path between the faces of the terminals, most of it being carried by the gas in circulation in the tube. To produce this condition it was only necessary thoroughly to exhaust the terminals, and then while the tube was excited introduce fresh gas until the tube had a low vacuum.

Electrical Review, May 2, 1900.

NOTE 96 — NITROGEN IN AN X-LIGHT TUBE

In Note 1, a tube was figured which regenerated by hydrogen. In subsequent notes simple regulators, both chemical and intermolecular, were described, by means of which this gas could be introduced, when the resistance had become too high. Further experience with hydrogen showed such vacuums might be unstable, therefore, on tubes with only one regulator not suited for commercial use. Under some circumstances the resistance might be equal to twenty centimetres of dry air, and the next moment might have fallen to less than one centimetre; after which it might as suddenly rise again. A more stable vacuum was the one mentioned in Note 23, with which dry oxygen was introduced. As this regulator is in commercial use, it may be considered practical, though after a time the tube gets dull, nor can its original brilliancy be restored by further additions of oxygen. This matter of dulness was referred to in Note 52, and has proved an interesting one to work on. In Note 76 some attempts to produce what was called "a groundwork" vacuum were mentioned; further experiments were made, some of which indicated that nitrogen had useful properties for this purpose. The appearances in the earlier experiments with this gas may have been due to other causes. In using nitrogen the simple means now generally used with the oxygen regulator suffice, but instead of filling the bulb with chemicals to produce oxygen, others to yield nitrogen may be employed; the necessary heat to liberate the gas being obtained from the current used to excite the tube, by placing the regulator bulb in a shunt circuit, with a spark-gap in series with it; the length of the gap determining the resistance of the X-light tube, for when this gets too high a spark jumps through the regulator bulb liberating nitrogen. Before writing this note such a tube was used on a six-inch Ritchie coil, run on the two hundred and twenty volt street circuit, using eleven hundred watts of energy in the primary and even with a condenser having a capacity of one hundred microfarads[67] the light was steady for six hours, the tube yielding the proper quality and amount of light for examining the heart and lungs when placed at a distance of three feet from the screen. It would, therefore, appear as if the regulator was of some value.

Electrical Review, May 30, 1900.

[67] The capacity is given me by Dr. F. H. Williams, who owned the apparatus.

NOTE 97 — ON THE RELATION OF OCCLUSION TO RESISTANCE IN AN X-LIGHT TUBE

The word occlusion is objectionable, because its meaning is, like that of polarization, indefinite. It is used here to express the attraction existing between particles of solids and gases. On the degree of this attraction depends the resistance of a vacuum tube. To be specific: take an X-light tube with two terminals of metal. Each of these terminals is a mixture throughout its mass of metal and gas, — particles held together by attraction. When we exhaust such a tube with a pump, we can get, in a short time, a vacuum equal to a millionth of an atmosphere, but the moment an electric current is sent through the terminals, then the pressure is increased; because the current has torn particles of gas from these particles of metal forming the surfaces of the terminals, sending them into the circulation. Further advances in diminishing the pressure are now slow if the current is continued, but after some hours of pumping and sending a moderate current from a twelve-inch Ritchie coil using fifty watts of energy in the primary, the vacuum has become higher, until at length the current will no longer pass, unless the energy is increased. If now the tube, having a nitrogen vacuum, is sealed from the pump and allowed to rest for a time, it will be found in sending a current through it that the resistance is less. Leaving out other causes mentioned in earlier notes, what is the reason of this? Gas has come to the surface from the interior, furnishing particles on which the charge rides the field between the terminals.

The charge is always said to exist on the surface, never penetrating the interior. That is well enough as calling attention to one character of electricity, but is not a true generalization. It would be better to say disassociated electricity resides on surfaces, but as electricity is what holds things together, it must exist within the mass. The reason the resistance[68] of a tube may rise when the vacuum is falling, is that the charge tears off particles from the surfaces of the terminals faster than they come up from the interior. This is why, in a seasoned tube, a powerful current raises the resistance more rapidly than a feeble one. What causes the particles to come up from the interior? This, — every particle or group of particles of the metal -in case the terminals are of metal- has associated with it an unknown number of particles of gas. As the electric stress has torn off particles of gas from the metal particles forming the surface, the tendency is for the particles of metal in the interior to give up a part of the gas they hold until the attraction is alike throughout the mass. When this has taken place none of the groups are satisfied, for each has now less gas attached. As a result, the particles are held with greater force, and to use one of Rowland's expressions, we must "cover them with bigger patches of electricity here and there"

[68] Note 1903. — When the term — resistance of a tube — is used in these notes, it refers to that condition of the X-light tube when there is a normal cathode stream from the front of the cathode. The stream may suddenly break, the current being otherwise carried through the tube. The resistance may then fall. The cathode stream may again suddenly form, the resistance increasing.

before the bonds of the surface groups can be ruptured, and in consequence the resistance of such a tube is higher, until finally it gets into a condition mentioned in former notes, where a very high potential is required to start the Varley cathode stream, the resulting X-light waves being so short they go as well through the dense bones as through the soft tissues. The tube is then useless for medical diagnosis. To produce the proper kind of light again in such old and seasoned tubes obstructions must be placed in the path of the flying cathode particles on their way to the target, so they may not strike too hard. This can be done by lowering the vacuum. But such a tube may not be as good as a fresh one, for it may take more energy to make an equal quantity of X-light.

Electrical Review, May 30, 1900.

NOTE 98 — HOW DOES AN X-LIGHT TUBE WORK?

The favorite question of the youthful Maxwell was — "What 's the go of that?" If the answer was not clear, he would say, "But, what is the particular go of that?" In attempting to learn enough to make an efficient X-light tube, the last question has often been asked, and failing to get a satisfactory answer, the following mental images have been set up to interpret past and for suggesting future experiments, for in Maxwell's Electricity, an answer to the question, What is an electric charge? was not found. The first image is, The Ether is Electricity. The second is, What we call Electricity is dissociated Ether. Applying these statements to an X-light tube in action we may look upon the ether between the terminals as polarized and partly disassociated by the energy applied. Between the terminals the field is made of ether units swung around and formed in lines, those at the ends being disassociated. At the surface of the cathode the free negative ether combines with the particles of gas held by the metal, leaving the positive ether to seize the negative of the next ether unit toward the anode, and so on through the lines until the ether units next the anode are pulled apart, leaving the positive particles to collect around the gas particles of the anode.

We then have lines of swung ether units between the terminals and free ether particles or electricity at each terminal. As we increase the energy applied to the tube there comes a time when the disassociated ether collected about the gas particles in the terminals tears them off and rushes them across the field, causing them to strike the opposite terminal with sufficient force to raise them to so high a temperature they become centres from which X-light originates. But if this were true why should not both terminals yield X-light? They do — as stated in previous notes — and Trowbridge, with his powerful generator, has not only shown there are anode as well as cathode rays, but that X-light can be produced in a tube having a continuous metallic conductor, instead of the usual terminals. Both of his observations are explained by the theory given. But for practical purposes why should the anode or target be the place from which X-light originates? The answer may be found in a phenomenon already spoken of in former notes; namely, amalgamation of gas with the terminals. To explain this in the shortest way it is necessary to state that in the process of preparing a good X-light tube the gas is removed more rapidly from the anode than from the cathode. If proof is required, pump two tubes, one with the current flowing from the anode to the cathode, the other with the current flowing from the cathode to the anode; then compare the two with the current flowing in the normal direction.

Accepting the statement as correct, it is obvious in producing X-light with a unidirectional current from a battery through a great resistance, as Trowbridge has done, we should expect the light to come from the anode, because the number of available gas particles held by the cathode after a tube is prepared for use may be greater than the number held by the anode, and therefore this would determine the predominating direction of the actual transfer of ether particles in the cathode stream; while so long as energy was applied to the system, interchange of partners among the polarized lines of ether units between the terminals in the tube would go on.

This theory permits of a graphic representation of the field representing tension and pressure at right angles, explains the swayings we interpret as transverse waves, and suggests one reason why X-light arising from the anode should be more apparent than that coming from the cathode. — Electrical Review, June 2, 1900.

NOTE 99—ON TUBES FOR GENERATORS OF LOW POTENTIAL

To get brilliant X-light with a small expenditure of force it is necessary to have a vacuum so high that particles of gas rushing from the terminals may meet with the least possible obstruction. When such a tube is used with a generator of low potential it is difficult to overcome the initial high resistance due to the force of attraction which holds the gas particles to the terminals. In pumping a tube, while sending the current through it, these particles come off in great numbers. Only by continued running until those remaining are held with a force which requires several thousand volts to overcome, can a tube be brought to a condition to produce X-light efficiently. As already shown, pumping is but a small part of the preparation of an X-light tube. With a good pump an X-light vacuum can be produced in a short time, but to remove enough from the terminals is a far longer process. To enable a low-potential generator to overcome the initial high resistance of a tube which had been properly prepared, a holder was arranged into which heat could be introduced while the tube was in use, the temperature being easily raised to as high degree as the glass would bear without getting soft.

When the vacuum had been lowered by heat -from gas driven from the glass-, and the resistance to the formation of the Varley cathode stream made less -by heat having partly overcome the attractive force between the gas and the metals of the terminals-, the low-potential generator had the power to send gas particles from the cathode and drive them against the target with sufficient force to produce X-light. When the current was started the vacuum by continued running fell, the tube producing too many heat-waves and too few X-light waves, because the particles from the cathode did not strike the target with sufficient force. As this state came on, the temperature of the tube was allowed to fall, until a condition was reached where, by a balance of the forces, the character of the light was maintained constant; it being only necessary to allow the tube to cool more as the number of particles in the circulation increased, thus condensing them on the glass. For repeating this experiment a tube should be in good condition; that is, the attraction between the remaining gas and the metal of the terminals should be of the proper degree for the generator with which the experiment is carried out.

In those cases mentioned in former notes, when by long use the resistance has grown so high -from continued exhaustion of the gas from the terminals-, a convenient degree of heat will not allow the current to liberate enough gas to form a Varley cathode stream, the tube cannot be used on a low-potential generator without other treatment. At this time the best way of recharging exhausted terminals is not known, though many attempts have been made. Having formed a theory that if the cathode could be heated it would take up gas as it cooled, — the gas being obtained from the supply collected by the glass in the normal working of the tube, as it was forced from the terminals, — in one of the experiments a tube somewhat like the one shown in Plate 29, Figure 59, Note 65, was used, only there was a hinge in the stem of the target to enable it to be dropped out of the field when the tube stopped working on account of the terminals being exhausted. In pumping, the tube was maintained at a temperature of five hundred degrees Fahrenheit to expel gas. The left-hand aluminum disk was a cathode, and the target was an anode. Then the target anode was dropped out of the field, the right-hand concave terminal made a cathode, the hinged terminal an anode and connected with the generator; the left-hand concave aluminum disk serving only as a target to receive the impact of the Varley cathode stream from the right-hand disk. After an hour the current was stopped, the left-hand concave disk allowed to cool, the tube being maintained at an unvarying temperature. When the tube was afterward cooled it gave X-light with the current passing in a normal direction. The experiment appeared to show there was some truth in the theory, and to have pointed out a direction in which valuable work might be done. This experiment is not offered as a satisfactory way of solving the problem of renewing exhausted terminals, but now Trowbridge has discovered X-light tubes can be excited by simply connecting the terminals to a storage battery of only twenty thousand volts, these observations may be of sufficient interest to mention, because with such a generator the cathode will be rapidly exhausted from the increased amperage we shall be tempted to use, for more amperage means more light, which is most desirable in medical work. As this new type of generator is silent, it will be of the greatest value in studying the heart and lungs by means of the apparatus shown in Plates 19 and 20, Figures 46 and 47, Note 47.

Electrical Review, June 2, 1900.

NOTE 100 — DOES THE ETHER CONDUCT?

When two great men make statements which appear to oppose each other, it is always desirable to find some reconciliation which may serve as a working theory to guide experiments. An attempt has been made to do this with the statements which follow, to help in understanding the phenomena of X-light tubes.

Maxwell said conductors were opaque. The ether therefore cannot conduct, for it is the type of transparency. But Trowbridge concluded a remarkable paper read before the American Academy of Arts and Sciences, April, 1897, with these words: "I am thus forced to the conclusion that under high electrical stress the ether breaks down and becomes a good conductor." If, as stated in a former note, we imagine the ether to be dissociated when we apply sufficient energy, we appear to reconcile these statements, for normal or whole ether is transparent and serves as a medium for the changes we call waves, but does not conduct. When dissociated, its particles forming new combinations with the differentiated ether we call matter, its properties are so changed as to give rise to the phenomena, electricity and conduction.

Electrical Review, June 2, 1900.

NOTE 101 — CONDUCTION IS A PHENOMENON OF MATTER

The fact of amalgamation between solids and gases, with its accompanying ether phenomena under stress, is of value to those who are working with the ether over a wider field than that of an X-light tube, extending even to gravitation itself, which latter aspect will be spoken of later. If all the particles of matter were removed from an X-light tube, it would not conduct by means of a normal cathode stream, however high the electro-motive force, until the stress overcame cohesion. When this state -which differs for different substances under electric stress, as it does under mechanical and chemical- arrives, particles of the terminals serve as carriers for the disassociated ether and rush across the field, producing the phenomena of conduction. If there were no internal terminals, the glass would act as such. Normal ether does not conduct.

Electrical Review, June 2, 1900.

NOTE 102 — MAXIMUM X-LIGHT ARISES IN THE FIELD OF GREATEST ETHER STRAIN

In earlier notes an attempt was made to show, contrary to the accepted opinion, the direction of the cathode stream, and therefore the chief area from which X-light arose, was influenced by the position of the anode in relation to the target -Note 15, Plate 5, Figure 1-. If, therefore, the phenomenon of X-light is a result of a stress applied to the ether, we should expect the effect to show most between the terminals, and this would explain why there was no X-light coming from the normal target in Note 15, Plate 5, Figure 1, when the ring was made an anode, for the normal target was too far from the field of maximum strain, which was of course between the terminals of the circuit to which the energy was applied, — in this case the ring anode and the cathode, from which vicinity

X-light arose. Plate 40, Figure 75, further illustrates this. Here the cathode is bifocal, but the direction of the cathode stream depends upon which of the two targets is made anode, X-light originating from the one which forms a terminal to the circuit. This tube was designed to throw some light on the ether disassociation theory already mentioned, and has no practical value, though one of a similar type has been recommended for stereoscopic work. The following observations show why such tubes are not of practical importance. Though the area from which most of the X-light arises is on the anode target, it also comes from other places, wherever the impact of particles shot from the terminals is forcible enough. In tubes of the type mentioned, in addition to the strain in the ether between the terminals, there is a condition of less strain over a large area, therefore when the particles of gas amalgamated with the terminals fly off, they not only go from the front surfaces, but also, in a less degree, from other parts of the metal, perpendicularly to its surface. As a result, the glass walls, particularly over a ring-shaped area surrounding the biconcave cathode, become a diffused source of X-light, while in properly designed tubes the energy is more delivered from the concave surface of the cathode. All energy otherwise used in a tube is not only wasted, but injures the definition. In attempts to design tubes this point should be remembered, the cathode being placed to encourage the normal stream from its concave surface.

Electrical Review, July 11, 1900.

NOTE 103 — AN X-LIGHT TUBE HAVING A TARGET TO ROTATE IN TWO PLANES, AND WITH A RESERVE CATHODE

Roentgen, who first used, in an X-light tube, Crookes' principle of a cathode stream focussed on a metal target, was also the first to apply the principle to a tube for alternating currents, inventing the double-focus type, which has, however, the defect of giving two sources of light, though for practical purposes this is not always a serious matter. In former notes a variety free from this defect was shown, the second light source being sent out of the field, but as tubes with three terminals are more difficult to construct, less use has been made of them. Now one is described in which the target rotates in two planes, — one parallel, the other perpendicular to the plane of the paper in Plate 41, Figure 76. In this way the angle made by the target with the axis of the cathode stream can be changed to see which is most effective. As the target also rotates about a central axis perpendicular to the surfaces on which the cathode streams strike, fresh metal can be brought to receive these impacts when holes have been made. This target is made one terminal, the second cathode being reserved as a storehouse of gas, to be used when the resistance in the circuit between the other cathode and the target has become such the light is not of the desired quality. As the stem of the anode is hinged, it may be dropped out of the field to allow the stream from one target to heat the other, when for this purpose they are both made terminals.

Electrical Review, July 11, 1900.

NOTE 105 — WHICH WAY DOES THE "CURRENT" FLOW?

Current is used here under protest and only to avoid making a new word. Several authorities were asked which way the current flowed, and always the answer was given in a tone showing the question was considered a foolish one. Yet when the second Maxwell question was asked: "But what's the particular go of it?" the answer was always unsatisfactory. Maxwell, with his acute mind, realized he did not know, as the following quotation from paragraph 568 shows: "So far are we from knowing its absolute value in any case that we do not even know whether what we call the positive direction is the actual direction of motion or the reverse." Therefore, this seems a suitable question to put to an X-light tube. In earlier notes the result was incidentally mentioned, but here, in its proper place, it may be dwelt upon.

Make a tube like the one shown in Plate 41, Figure 76, with two concave aluminum terminals exactly alike. Exhaust, while hot, to a high vacuum without sending any "current" through it. Make the right-hand terminal positive, the left-hand negative, not using the central target as part of the circuit. Send a "unidirectional" current through the tube and continue pumping. When the resistance of the tube is equal to ten centimetres of dry air, reverse the current, making the left-hand terminal positive and the right-hand negative. It will be found the resistance to the development of the Varley stream is greater than in the first position. This is the same phenomenon mentioned in former notes. Consider its bearing on the direction of the "current." By the preliminary pumping without "current" the gas was mostly removed from the space enclosed by the walls of the tube, what was left being chiefly amalgamated with the terminals. Already it has been shown under these circumstances it is the gas amalgamated with the terminals which carries the charges through the ether between the terminals. Now, the more the gas is driven out of the terminals, the higher becomes the resistance of the tube, therefore, when one terminal is more quickly exhausted than the other, we may consider this was the direction by which it was easiest for the strained ether to relieve itself. But gas came out of both terminals, therefore, if the word current is used, it should be in the plural. Those who love the work of Faraday will be glad of it. With currents alternating so rapidly they approach the electro-magnetic phenomenon of light, charges would not be carried by matter acting like projectiles, for the particles, owing to their inertia, would not have time to move across an appreciable space in the ether. All they could do would be to tremble, the energy spreading as ether vibrations. There would be no currents, the strain being relieved by the ether vibrations.

Electrical Review, August 8, 1900.

NOTE 106 — RELATION BETWEEN GAS AMALGAMATION AND TESLA LIGHT

To-day in reading Tesla's striking lecture before the Institution of Electrical Engineers, in

London, in 1892, one passage on which the phenomenon of gas amalgamation appears to bear attracted attention. He held one of his vacuum tubes in his hand while standing in the static field, or, as it should be called, the space of ether strain, for a field is a flat, while this has three dimensions. The tube glowed with a brilliant light. Taking another with a higher vacuum, he showed under the same conditions it was dark. A discharge from a Tesla coil was then sent through it, when it became luminous, like the first, after being separated from the coil. He then went on to say: "I may put it away for a few weeks or months, still it retains the faculty of being excited. What change have I produced in the tube in the act of exciting it? If a motion imparted to the atoms, it is difficult to perceive how it can persist so long without being attended by frictional losses, and if a strain in the dielectric, such as a simple electrification would produce, it is easy to see how it may persist indefinitely, but very difficult to understand why such a condition should aid excitation when we have to deal with potentials which are rapidly alternating." It appears the explanation of the problem is this: The particles of gas which, in previous notes, have been shown to be amalgamated with the glass and terminals, were some of them sent into the free space in the tube by the stress of the coil, and therefore the usual bombardment by these particles could go on as in the tube which had a lower vacuum, for in this second tube the vacuum was now lowered.

Electrical Review, August 8, 1900.

NOTE 107 — A LIGHTNING STORM MAY BEGIN QUIETLY

In Note 104 was shown a lightning flash of striking character. Here is described another type. We usually think of lightning storms as coming from somewhere, — in this part of the country generally from the southwest, and passing over; but such a course is not necessary. My camp is about eleven hundred feet above the sea, on an elevation overlooking the immediate country, and guarded by a mountain wall from five to ten miles distant, extending from north to southwest. On this wall, or within it, lightning storms frequently arise. The night of July seventeenth there was clear starlight. Slowly a little cloud arose, forming out of the pure sky, glowing with a rose-pink light, beautiful in the darkness. No noise could be heard. The cloud increased in size, becoming at intervals more brilliant. Occasionally could be seen the irregular bright lines which Faraday claimed were simply the illuminated edges of a dark cloud behind which the lightning was playing. Such could not have been the case here, for when another suffused glow came, there was no cloud outline to correspond with the shape of the bright band. For an hour photographs were taken at intervals, before the glow discharge rose sufficiently in potential to cause a flash strong enough to be heard. Then the atmospheric disturbance rapidly increased, the outrushing under-wind arose, and a powerful storm was soon overhead. Here was the phenomenon that Tesla, in his lecture already referred to, spoke of: "Such discharges of very high frequency, which render luminous the air at ordinary pressures, we probably often witness in Nature. . . . In trials of this kind the experimenter arrives at the startling conclusion that to pass ordinary luminous discharges through gases, no particular degree of exhaustion is needed, but that the gas may be at ordinary or even greater pressure." — Electrical Review, August 8, 1900.

NOTE 108 — THE BEARING OF THE ETHER DISSOCIATION THEORY ON THE IONIZATION THEORY OF SOLUTION

We owe to Helmholtz and the great physical chemists, like Arrhenius, Ostwald and Nernst, the development of the modern view of solution; namely, that the dissolved substance is dissociated into ions having different electric charges. For example, in dilute hydrochloric acid almost all the HCl is broken into $\overset{+}{H}$ and $\overset{-}{Cl}$ ions.

Helmholtz stated the law clearly: "Since the complete equilibrium of electricity is produced in the interior of electrolytic liquids as well as in metallic conductors by the weakest distribution of the electric forces of attraction, therefore it must be assumed that no other force is opposed to the free movement of the positively and negatively charged ions, save the forces of their electrical attraction and repulsion." Now, owing to the behavior of some substances, for example, iron, it is necessary for the theory to assume iron ions have a greater positive charge in some cases than in others, three times as great in $FeCl_3$. Thomson's theory of an atom states it is composed wholly of corpuscles which are the ultimate particles of electricity.

It is difficult at present to reconcile these two theories. As there are more facts in favor of the first, we may consider the charge as different from the atom, the ion getting its varying charge from elsewhere -Theoretical Chemistry, W. Nernst, translated by Professor Palmer, page 329-. The theory of a charge given in former notes explains this by saying electricity is dissociated ether. When a substance is dissociated in solution into ions having charges of different signs, the number of ether particles broken into positive and negative units varies with circumstances; the number will be governed by the needs of the ions. In the case of $FeCl_3$, three ether particles will be broken, the three positive units going to one iron ion, forming with it a system having a threefold electric charge Fe^{***}, while of the three negative units one will go to each of the three chlorine ions forming three systems each with one negative charge, $\overline{Cl} + \overline{Cl} + \overline{Cl}$. This consideration meets the statement of Faraday, who said positively when a charge of one sign appeared, then somewhere there must be an equivalent charge of opposite sign. Viewed in this light, there is no objection to an ion having any number of unit charges which the theories of chemistry require.

Electrical Review, October 31, 1900.

NOTE 109—THE STRUCTURE OF THE ATOM AS SEEN BY CATHODE RAYS AND X-LIGHT

Varley discovered the cathode stream, deflected it by a magnet, showed the force of its impact on a pivoted mica vane, stated it was composed of molecules of the residual gas in the tube charged with electricity. Since Varley published his results, two theories of the cathode stream have been held by physicists, the Varley or material particle theory and the ether theory. As those who hold the ether theory do not explain why the cathode stream is deflected by a magnet, only the material particle theory will be considered. In the form stated by Varley it is now abandoned by physicists, because the facts of chemistry show electricity breaks molecules into ions. In consequence, Schuster said the particles in the Varley stream were ions such as are present in electrolysis. Therefore the particles would be as large as atoms. In the case of oxygen they might be larger. Other observers have considered the particles much smaller. Weichert made the first determination of the relation e/m. Finding it to be between 20×10^6 and 40×10^6 c. g. s. units, or three thousand times as great as the ratio for the hydrogen ion in electrolysis, he chose to consider the particles in the cathode stream were one three-thousandth of the size of the ions in electrolysis. An attempt will be made to use this theory to show why when a cathode stream strikes a platinum target in a reflecting focus tube, we get more available X-light than with an aluminum target. The usual explanation given is that less X-light is reflected from and more transmitted by aluminum. An endeavor will be made to explain why aluminum is more transparent, and then to prove there are other reasons for the superiority of a platinum target. In attempting the construction of an efficient X-light tube there was a doubt which theory of X-light to accept for an experimental basis, on account of objections to the material particle theory as well as to the ether theory. The former gave no reason why the rays were not deflected by a magnet except to say they were not charged. It was difficult to understand how particles thrown from a highly charged body could escape without a charge. But admitting they had no charge it seemed as if they should have acquired one from passing through a charged leaf of aluminum. In these experiments they have not yet been deflected after such passage. If they were ether phenomena like light, or, in other words, electro-magnetic manifestations, it was difficult to see how a metal could be transparent to them, for Maxwell's theory required metals to be opaque because they were conductors.

There appeared to be inseparable obstacles to both theories. The material particle theory could not be considered, for it was not in accordance with simple experiments. The ether theory seemed to oppose the electro-magnetic theory of light, which required aluminum to be opaque to X-light, if this was an electro-magnetic phenomenon, but it was not opposed by any experiment. Therefore it was sought to reconcile the transparency of aluminum with the electro-magnetic theory of X-light. On the usual theory that the atoms of metals were solids of the same size and conductors, it was difficult to see why aluminum should be more transparent than platinum. The particles of metals cannot be transparent, for they conduct. The transparency of a metal, therefore, must be due to the ether it contains. A transparent metal should therefore contain more ether than an opaque one. But how shall we get more ether in a mass of aluminum than in a mass of platinum, when the atoms are of the same size and solid, and the ratio of the atomic weights to the densities about the same, for this shows the spaces between the atoms filled with ether cannot be very different in the two metals. By supposing the atoms made of systems of sub-atoms with ether between them, the difficulty of the other theory might be overcome. These sub-atoms exist in the cathode stream. They are formed of the ultimate units from which all the elements were made. The theory that the particles in the cathode stream are these ultimate units cannot be the true one, for in former notes it was shown the cathode stream particles had a familiar spectrum composed of a number of lines. When we find sufficiently disruptive forces to break up the cathode stream particles, we shall not get a familiar spectrum from the ultimate units resulting. As these ultimate units must be of the same size and weight, there must be less of them in a light atom of aluminum than in a heavy atom of platinum to account for a difference in atomic weight, and there must be more space between them. As this space is filled with ether, a light atom like aluminum should be more transparent to X-light if this is a very short vibration in the ether. The theory indicates ultimate units are opaque because they conduct, while the ether between them is transparent and does not conduct. If we think of these ultimate units not as matter, but as differentiated ether, the reasoning will be the same. This view is probably the true one, for it simplifies our idea of the universe. That ether is transparent and does not conduct is no objection, for we should expect differentiated ether to differ from ordinary ether.

The following experiment indicated the greater transparency of aluminum was not the chief reason why an aluminum target was not as efficient as one of platinum. A platinum target was covered on the face struck by the cathode stream by a thin veneer of aluminum. If the loss in efficiency in an X-light tube with an aluminum target had been due to the transparency of the aluminum, such a target should have been almost as efficient as one entirely of platinum, and should have acted toward X-light as a glass mirror silvered on the back would have done to ordinary light. The X-light passing through the aluminum should have been thrown back, not lost, for it could not have passed through the platinum back any more than through a regular platinum target. The tube did not give as much X-light. The following explanation was given. The particles of the cathode stream are not stopped so abruptly when they strike aluminum as when they strike a heavier metal. On the solid atom theory we might suppose the atoms of platinum being heavier would produce this result, but this theory cannot explain the small size of the particles in the cathode stream, and it does not explain why one atom is heavier than another, except by saying such is the nature of atoms. The compound atom theory mentioned will explain the small size of the cathode stream particles; why they have a familiar spectrum and the fact that aluminum is transparent to X-light and is a conductor of electricity. On the compound atom theory, the more open structure of aluminum would not stop a flying particle in the cathode stream so quickly, allowing it to penetrate further. In former notes a high temperature was said to be the cause of X-light. We should not expect a cathode stream particle when slowly stopped to get as hot as when stopped more abruptly, for the energy of heat conversion would be extended over a longer period. In a future note it may be well to consider the objections which can be raised to the theory that all substances are composed of the same ultimate units which are conductors and opaque. — Electrical Review, September 28, 1900.

NOTE 109 A — THE CATHODE STREAM AND X-LIGHT [69]

The Cathode Stream. — There are two opinions about cathode rays. First, The rays are some phenomenon in the ether. Lenard considered them smaller transverse waves than those of light. Michelson thought they were ether vortices. Second, They are flights of material particles. Varley, who published his results in 1871, considered the cathode stream composed of molecules of the residual gas in the vacuum tube, charged with negative electricity. He deflected the stream by a magnet; showed the force of its impact on a pivoted mica vane. Crookes, who illustrated the earlier work of Varley and Hittorf by beautiful experiments, agreed with Varley as to the nature of the stream. He said the cathode stream par-

[69] This paper was not published in the same journal as the others, as it was intended for a summary of some of the theories mentioned in earlier notes. On this account it may be passed over except by readers who are interested.

ticles left the cathode normal to its surface, moved in straight lines, coming to a focus in the centre of its curvature. Experiments showed that neither theory of the cathode stream could explain all the facts. If it was possible to remove all the ether from an X-light tube, there would be no X-light, for no cathode stream could form, because a strain in the ether is essential.

The Ether Theory.—One characteristic of the Varley or cathode stream has not been explained by this theory; the stream can be deflected by a magnet, X-light arising where the deflected stream strikes. As there are also other objections, the pure ether theory will not be further considered. The experiments supposed to support it apply as well to the material particle theory.

The Material Particle Theory.—Since Varley's experiments the opinion has slowly grown that the particles in the cathode stream are not as large as molecules. The facts of physics and chemistry appear to prove electricity breaks molecules into ions. Schuster therefore said the particles were the same Faraday ions as appear in electrolysis. Other physicists have further reduced the size, Weichert giving it as one three-thousandth of a hydrogen atom, and the speed as one-third that of light. In regard to this speed, Rowland, in a remarkable paper before the American Physical Society in 1899, said there was no way of producing this velocity in a body, though it fell from infinite distance on the largest aggregation of matter in the universe. Weichert made the first determination of the relation between the charge and the mass of a cathode stream particle. He gave this as

20×10^6 to 40×10^6 c. g. s. units. As this ratio is about three thousand times as large for a cathode stream particle as for a hydrogen ion in electrolysis, this physicist thought he must either assume a charge three thousand times as large, or a mass one three-thousandth of a hydrogen ion. He chose the latter, and other physicists have followed, some being willing to allow a cathode stream particle to be as large as one five-hundredth of a hydrogen ion. There is no proof of these suppositions. Weichert might have had the same ratio mean some other size for the particles. Kaufmann found this ratio was not affected by the gas or the terminals in a vacuum tube. Authorities will not be quoted further, but their statements will be grouped to show what is called a sufficient explanation of the cathode stream by those who hold the material particle theory.

First, The cause of the cathode stream is a repulsion between the cathode and the charged particles of gas in the tube. This repulsion is due to the particles coming in contact with the cathode receiving charges of the same nature. Second, The particles are given off from the cathode perpendicularly to its surface, and move in straight lines, coming to a focus at the centre of curvature of the cathode. Third, The direction of the particles in high vacua is independent of the position of the anode. Fourth, All the cathode stream particles move with equal speed, which is of the same order as that of light; they have the same charge, are of the same size. Fifth, In the cathode stream the charges are always carried by the same particles in all tubes, with any gas, with every cathode. Sixth, The cathode stream particles are the same in every atom in the universe. They are the ultimate particles of electricity. Seventh, In the cathode stream only one particle is detached from an atom. The remaining part has a positive charge. Eighth, The particles in the cathode stream are those liberated by ultra-violet light from a charged body, move with the same speed, have the same charge. Ninth, The particles in the cathode stream are those producing Becquerel light. Tenth, The particles in the cathode stream are the ultimate units from which the elements are formed. Each has a mass of one three-thousandth of a hydrogen atom.

Some of the experiments with X-light tubes which have been described in the Electrical Review during the last three years will be now mentioned, grouping them under the headings given:

First, The cathode stream is a purely material particle phenomenon, with which the ether has no part. The sole cause of the cathode stream is a repulsion between the particles of residual gas in the vacuum tube and the cathode. These two assertions are mentioned together, because one experiment applies to both. An X-light tube was made with a biconcave aluminum cathode in the middle of its bulb. At each end of the tube was a platinum target. If the cathode stream was not affected by the ether, and depended entirely upon the repulsion between the cathode and the particles of residual gas, two cathode streams of equal intensity should have arisen from the cathode, producing the same amount of X-light at each target. All the X-light arising from either came from whichever target was made an anode. The experiment proved, first: a space of strained ether was necessary, X-light arising with greatest intensity where the ether was most strained; second, the attraction of an anode was a cause of the cathode stream as well as a repulsion by a cathode.

Second, The particles of the cathode stream are always given off from the cathode perpendicularly to its surface, move in straight lines, coming to a focus in the centre of curvature of the cathode. Any one with experience can see the focus of the cathode stream when well developed in an X-light tube. By means of a pin-hole camera it may be photographed. Both methods prove the distance varies not only with the degree of exhaustion in the tube, but also with the potential of the driving current. A tube was made with a movable anode, whose distance from the cathode could be changed by a magnet. Under the conditions required for the economical production of X-light it was found necessary to have the target at twice the theoretical distance for it to be in the focus of the cathode stream. This experiment showed the particles did not move in straight lines provided they left the cathode normal to its surface, nor did they come to a focus at the centre of curvature. The explanation offered was as follows: the particles of the cathode stream have the same kind of electricity, therefore they repel each other, coming to a focus beyond the place required by the accepted theory.

Third, The direction of the particles in the cathode stream is independent of the position of the anode at high vacua. The experiment described in paragraph one appeared to disprove this, but another is also mentioned. An X-light tube was made with connecting bulbs, one containing the usual cathode and anode. In the other, encircling the stem of the cathode already mentioned, as it passed through this second bulb, was a ring that could be made an anode. When the tube was connected in the usual way with the generator, the cathode stream arose from the concave side of the cathode, came to a focus on the normal anode, giving bright X-light. This anode was then disconnected from the current. The supplementary ring terminal was made the anode. Under these conditions no cathode stream arose from the usual side of the cathode, consequently no X-light was produced at the normal anode. X-light arose in the other bulb from the spreading streams of cathode particles given off from the back or convex side of the cathode.

Fourth, The cathode stream particles are always of the same size, move with the same speed, and carry the same charge. If these assumptions were true, we should always get the same effect when the particles struck the target in an X-light tube. We do not. Every one long familiar with the construction of such tubes knows the quality of the light varies with the resistance of the tube. In the determinations of the speed no sufficient account was taken of the retarding effect of the gases in circulation in the tube. If we try to keep this constant, even then the effect produced by the impact of these particles on the target in an X-light tube varies from other causes. To show this a tube was made in which the ordinary cathode could be covered by mercury. With the usual cathode the tube gave good X-light. With the mercury cathode there was not enough X-light to see the bones of the hand, but the whole tube was filled with a brilliant white light. This was explained by saying the particles in the cathode stream were heavier when the cathode was mercury than when it was aluminum, and the stream was composed of some light gas. In consequence the particles did not strike the target at so high a velocity, and when stopped were therefore not heated to so high a degree; hence were not such efficient centres of radiation for the short ether movements we call X-light, most of the energy appearing as ordinary light instead. Some of the experiments on which was based this heat theory will be mentioned later. If the particles in the cathode stream were always of the same mass, all cathodes should lose equally in weight in the same time, with the same amount of current. They do not. It was also found when the gas had been considerably removed from the terminals, cathodes of heavy metals lost in weight more rapidly than those of light metals, like magnesium and aluminum.

Fifth, In the cathode stream the charges are always carried by the same particles, in all tubes, with any gas, with every cathode. An X-light tube was exhausted while using heat and heavy surges until it yielded no X-light. Had the particles been removed? Surely such a wonderful result was never before accomplished so easily. The explanation was simpler. We depend upon gas amalgamated with the terminals to make an efficient cathode stream in an X-light tube. When the cathode stream no longer forms, we have removed too much of this gas. Consider here the experiment with the mercury cathode already mentioned.

Sixth, The cathode stream particles are the same in every atom. They are the ultimate units of electricity. If true, how explain the experiment mentioned in paragraph five? Why should X-light have stopped? The terminals of the tube were constantly connected with a generator supplying electricity. They were good conductors. They were kept charged to a high degree. Is it not simpler to accept the explanation given in paragraph five? Consider another experiment. An X-light tube was exhausted by heat and pumping until no gas appeared in the pump. A current was then sent through it, producing X-light. Much gas appeared in the pump. The bubbles continued so long as X-light was produced. When, by continuing the current and pumping to remove the gas thus driven out of the terminals, the X-light died out, the bubbles stopped. While there were bubbles there was a normal cathode stream and X-light. Were the bubbles composed of the ultimate particles of electricity? Is electricity a gas with a familiar spectrum, or were these bubbles simply a gas coming out of the terminals, thus forming a cathode stream as stated in paragraph five?

Seventh, In the cathode stream only one corpuscle can be detached from an atom, the remainder of the atom being positive. According to this theory, when the tube arrived at the condition mentioned in paragraphs five and six, — that is, when the normal cathode stream no longer formed, — the cathode should have been left with a positive charge. The charge was negative.

Eighth, The particles in the cathode stream are those liberated by ultra-violet light from a charged body, move with the same velocity, have the same charges. If true, we should get X-light from a cathode stream formed by allowing ultra-violet light to fall upon a cathode in an X-light tube connected with a capacity.[70] Sufficient X-light has not been made in this easy way to use in medicine.

Ninth, The particles in the cathode stream are those producing Becquerel light, have the same charges, move with the same velocity. If true, we could produce X-light from a vacuum tube with a radio-active cathode, without an electric generator. It would only be necessary to exhaust the tube to the usual X-light vacuum. The particles in the cathode stream from the radio-active cathode would then meet with no more obstruction on their way to the target to produce X-light than would be encountered by those of a cathode stream formed in the ordinary way. A distinguished American physicist expressed the opinion that the radio-active substances would be so intensified as to act as substitutes for the complicated and troublesome apparatus now required for producing X-light for medical purposes. Having a high regard for his opinion, experiments with X-light were abandoned to work with these substances. Experiments showed the light from them was different in character from X-light, suffering

[70] For the use of electrons in therapeutics refer to Note 179. For an electron generator to Note 179 D.

diffusion in the tissues like ordinary light to such an extent the bones even of the hand were not visible. The experiments indicated a difference, perhaps in velocity, between the units in the cathode stream and those of the radio-active substances, because the character of the two resulting radiations toward human tissues was not the same when produced in the same vacuum. Experiments of this nature require time and money. The results were disappointing, for the interest in the subjects mentioned in this paper arose from a wish to find the most efficient radiation for the relief of human suffering.

Tenth, A cathode stream particle has a mass only one three-thousandth of a hydrogen atom. The particles are the ultimate units of which all the elements are composed. That atoms are compound is probably true, though not yet proved by experiment. The theory explains phenomena better than that of the indivisible atom. That the particles in the cathode stream are the ultimate units is absurd.

A few suggestions in regard to each theory are made: On the theory of indivisible atoms, how shall we explain differences in atomic weight, except by saying that such is the nature of atoms? This is not a satisfactory answer to an active mind. On the theory of a compound atom it may be explained by saying a light atom has fewer ultimate particles than a heavy one, for as each particle must have the same weight there would be more in a heavy atom than a light one, to account for differences in atomic weights. That the particles in the cathode stream, however small, are not the ultimate particles of which the universe is composed, is shown by their having a familiar spectrum. If ultimate units could be made to give a spectrum, it would be a new one. In this connection a statement is mentioned which was made in the notes already referred to: In working with X-light tubes the spectrum of hydrogen was obtained in the cathode stream though other gases were in the tube. Therefore, before we reach the ultimate units of which the seventy-five or more elements are composed, more powerfully disruptive forces than those in the cathode stream must be used. The so-called ultimate, indivisible corpuscles of this stream cannot be the final units because they have a familiar spectrum, vibrating in too many ways at approximately the same temperature. The experiments published by Trowbridge in this Journal for September are the most important contribution to celestial physics since Kirchhoff proved the law of exchanges and told the nature of the Fraunhofer lines. Trowbridge always obtained the spectrum of water vapor in the cathode stream when a condenser was used. Therefore the cathode stream particles are not necessarily elementary. If such minute particles are compound, it shows, when elements combine, it is not their atoms which unite to form new molecules; the combination is far more intimate, a union of the particles of which atoms are composed. Long before we reach the heart of nature the present ultimate corpuscles will look to us more complicated than a wilderness of solar systems.

The X-rays. — First, Roentgen considered them longitudinal vibrations in the ether.

Second, Jaumann believed they had also a transverse component. Third, Goldhammer stated they were short transverse vibrations differing from light only in size. Fourth, Stokes advanced a theory of irregular pulses in the ether, partly positive, partly negative. Fifth, J. J. Thomson modified Stokes' theory. He believed when a cathode stream particle was stopped, its charge performed a single oscillation, giving rise to a pulse in the ether. Sixth, Michelson suggested that X-rays might be ether vortices. Seventh, Other physicists believed they were flights of material particles. This list of great names might easily be made longer. Yet what is known of the true nature of X-light? Nothing. A few suggestions will be made, and one or two experiments described: J. J. Thomson has accepted most of Weichert's views of the cathode rays, and Stokes' ideas of the X-rays. He believes when a corpuscle is stopped, there arises in the ether a pulse whose thickness is equal to the diameter of a corpuscle. These pulses are the X-rays. According to this theory, the thickness of the radiant area on the target from which X-light arises cannot be greater than the diameter of one of his corpuscles, having a mass one-thousandth of an atom of hydrogen. Estimate the thickness on this basis. As a preliminary it is necessary to know the diameter of a hydrogen atom. This requires a liberal use of the imagination, as proved by the different estimates. Kelvin said an atom, or a molecule -he did not attempt to distinguish them-, was from one ten-millionth to one-millionth of a millimetre in diameter. Meyer considered them smaller than a sphere one-millionth of a millimetre in diameter or as small as 0.2×10^{-7} centimetre. The physical chemists require us to believe a molecule is not a solid. Its atoms are arranged with ether between them. The diameter of an atom, therefore, is not equal to half the diameter of any molecule with more than one atom, while in complex molecules its proportion is smaller. Atomic diameters are probably not greater than one three-millionth of a millimetre. The corpuscle theory of the cathode stream gives the mass of a corpuscle as not more than one-thousandth of a hydrogen atom. The diameter of a corpuscle would not exceed one thirty-millionth of a millimetre. This, then, would be the depth of the radiant area on the target from which X-light could arise.

Consider the following experiment: An X-light tube had its target placed at an angle of ninety degrees with the axis of the cathode stream. As close as possible to the area struck by the cathode stream was a narrow passage in a block of platinum, with openings raised one millimetre above the surface of the target, the length of the passage parallel therewith. Under these circumstances, if X-light arose only from a radiant area on the target, whose depth was measured by one thirty-millionth of a millimetre, direct rays could but to a small extent have illuminated the passage, for this was on the top of a cliff thirty million times as high as the depth of the radiant area at its base, in deep shadow, except the opening nearest the radiant area. If the usual theory had been true, no bright image should have been formed on the fluorescent screen, by light coming through the passage.

The light was so bright Fomms' bands were photographed with a short exposure. The experiment also appeared to show X-light was not composed of the reflected ether vortices of the cathode stream or of minute material particles. As these are supposed to move in straight lines, they would have had difficulty in going into the passage in the platinum block to illuminate the screen brightly. Again, how could material particles shot from a charged anode escape having a charge and being reflected by a magnet? Suppose they did escape without a charge. When they went through charged aluminum, they ought to have received a charge and been deflected by a magnet. They were not deflected. Was not the theory of X-light advanced in my notes a better one? This was the theory: When the particles of the cathode stream strike the target, they are heated sufficiently to cause them to be radiant centres, from which the short ether waves we call X-light arise. As time is required for heat to decline, the particles are sufficiently hot, when they have rebounded opposite the opening of the passage, to be radiant centres. The wave-fronts, therefore, go directly through the passage to the fluorescent screen, brightly illuminating it. The word heat is used not to distinguish this from electro-magnetic phenomena, but to express a more persistent state in the radiant particles of the cathode stream, after they have struck the target, than that represented by the single pulse of the usual theory of X-light. An experiment bearing on this heat theory is mentioned. An X-light tube was made with a hollow target. The area struck by the cathode stream could be cooled to a low temperature. When so cooled there was less X-light. This tube under the title of the A-W-L tube was made commercially, proving capable of converting a large amount of electricity into X-light, because with any cathode stream it was impossible to melt the target. A simpler tube was designed for general use. The target rotated on an axis. Fresh metal could be brought to receive the force of the cathode stream when a hole had been melted. Before closing this paper, the structure of the atom as seen by the cathode stream and X-light will be considered. After Roentgen discovered some of Lenard's rays would show the bones of the hand, S. P. Thompson found the heaviest metals made the best targets in X-light reflecting focus tubes. The reason usually given is that light metals like aluminum allow X-light to pass through them, this part of the light being lost. Why should aluminum be transparent to X-light if this is an electro-magnetic phenomenon like ordinary light? Maxwell's theory requires conductors to be opaque. Aluminum is a good conductor and should be opaque to X-light. It is transparent. If X-light is an electro-magnetic phenomenon, we must find some way of explaining the transparency of aluminum. Consider first the solid atom theory. As the nature of a substance depends on its atoms, conductors must have opaque atoms if these are solid. If X-light is an electro-magnetic phenomenon, it cannot travel through such solid conducting atoms. If it passes through a metal with solid atoms it must pass in the ether between them. If one metal is more transparent than another, the more transparent must contain more ether. On the solid atom theory how can we get more ether in aluminum than in platinum? The solid atoms are of one size. There are about as many of them in aluminum as in platinum, for the ratios of the atomic weights are about the same as the ratios of the densities. There is not enough difference to account for aluminum being forty times as transparent as platinum. As we do not find enough difference in the amount of interatomic ether to account for the difference in transparency, we must give up the solid atom theory, for it fails here as it does in attempting to explain the cathode stream. Both phenomena require a compound atom. But the cathode stream theory, that the particles into which the atoms are broken are the ultimate units, cannot be true, for they have a familiar spectrum. A theory of the atom must meet these difficulties. The following is suggested. The atom is made of sub-atoms. The sub-atoms are the cathode stream particles. There are as many kinds of sub-atoms as there are elements. We should expect the cathode stream particles, therefore, to have familiar spectra. The sub-atoms are compounds. They are made of the ultimate units of which the elements are composed. These ultimate units have the same size and weight. As the atoms have the same size and different weights, light atoms must contain fewer ultimate units than heavy ones. There would be more space filled with ether in a light than in a heavy atom. When an electro-magnetic phenomenon passes through an atom of a conductor, it can only travel in the contained ether, for this is the only transparent part. The atom with the most ether would be most transparent. Aluminum, having more ether and fewer opaque particles, would be more transparent than platinum. Apply this theory to the following experiment, intended to show that the transparency of aluminum is not the only reason why aluminum is less efficient for a target in an X-light tube than platinum. A tube was made with the usual platinum target, covered with a thin veneer of aluminum on the surface struck by the cathode stream. Had the transparency theory been the true explanation, such a target should have acted toward X-light about as a glass mirror, silvered on the back, would have to ordinary light. As the X-light passing through the aluminum struck the platinum, only a little more could have been lost than with a target entirely of platinum. This was not an efficient X-light tube. The following explanation was given. When a cathode stream particle strikes an aluminum target, it is not so abruptly stopped as by a heavier metal. The heat of impact is not so high, the energy conversion extending over a longer time. The particles must be less efficient sources of X-light, if this is due to a high temperature. But why should a heavy metal target stop a flying particle more abruptly than a lighter one? Aluminum on the compound atom theory given is a more open structure than platinum: on this account it would stop a flying particle less abruptly.

American Journal of Science, November, 1900.

NOTE 110—THE EXPLOSION OF A STATIC MACHINE PLATE

An electrical engineer who was adjusting a wattmeter in the basement went to the work-room, starting the large generator previously mentioned in these notes. He left it running at such speed one of the plates exploded. Fortunately, the machine was stopped in time to prevent others from following. The matter is mentioned to show how thin a plane must have been occupied by those of the flying particles which were of any considerable weight. Although there were fifteen other plates, three of them within five centimetres of the broken one, none were injured, but everything in the plane of the broken plate was struck, glass fragments cutting through wood and glass. The plate was nearly two metres in diameter, yet after the accident the largest piece was about twenty-eight centimetres across.

There were over one million smaller ones besides the fine glass dust that could not be easily reckoned. As these large static machines have been mentioned as suitable for fluoroscopic work in large hospitals, on account of the steadiness of an X-light tube when excited by them, this precaution is added: the speed should not exceed two hundred and forty revolutions a minute. At this speed the edges of the plates are moving about four-fifths of a mile a minute. This generator, which has eight revolving plates each six feet in diameter, has been run two hundred revolutions a minute continuously, night and day for several days, in experiments with hydrogen vacuums.[71]

Electrical Review, October 31, 1900.

[71] Note added 1903. — This type of generator is too expensive to make and repair to be of general service in medicine. Those writers who claim induction coils are not suited for diagnosis with the cryptoscope because the

NOTE III — HOW TO PUMP AN X-LIGHT TUBE

In former notes it was shown, we depended upon gas amalgamated with the terminals to make an efficient cathode stream and X-light. When the gas is exhausted, the cathode stream stops with ordinary potentials, for there is nothing to carry the current across the space of strained ether between the terminals. Ether cannot conduct electricity, for it is transparent, and Maxwell has shown conductors are opaque. The cathode stream can be started only by furnishing an available supply of fresh gas. This may be done in several ways. Gas may be brought out of the terminals, though apparently exhausted, by using more force; that is, a more powerful generator. Gas may be recovered from the glass walls of the tube by heat. Gas may be introduced by intermolecular regulators from some source outside the tube. Gas may be introduced from chemicals in a supplementary bulb connected with the space enclosed by the tube. When gas is introduced in any of these ways, this is what happens: Part of it unites with the terminals, giving the electric current something on which to ride across the ether space between the terminals. So little gas may be introduced as not to lower the vacuum, after a moment has been allowed for it to unite with the terminals, and yet the resistance of the tube will be much lower. This is the same phenomenon referred to in former notes, and here again spoken of, for repetition is the only way to im-

X-light from a tube excited in this way is not steady, are mistaken. The clearest views of the internal organs seen during the seven years of these experiments have been with X-light produced by induction coils.

press the mind. The procedure, then, in pumping a tube is not only to exhaust the glass and the space it encloses, but to remove enough gas from the terminals by the current to prevent it from coming out so fast in use as to make the vacuum too low for the tube to be valuable. To exhaust the glass and enclosed space, heat and pumping are sufficient, but to remove the proper amount of gas from the terminals is an art which requires experience to master. It is also essential to know how much force will be applied to the tube when it is used. For example, if it is to be excited by a common static machine where the amperage is small, the terminals should be left quite full. If a large coil and an electrolytic break are to be used, the terminals must be much more exhausted. But with the best tubes there comes a time when the available supply of gas has been exhausted. Then the best means of restoring it should be sought. If more gas is taken from a regulator, which is the common method, then hydrogen, as recommended in earlier notes, is valuable.

Electrical Review, October 31, 1900.

NOTE 112 — X-LIGHT APPARATUS FOR PHYSICIANS IN THE COUNTRY AND OTHERS

The time will come when every physician will use X-light in diagnosis and treatment. At present the number employing it is very limited. One reason is the defective character of most of the commercial apparatus. In cities where the street current is available, it is practical to purchase from several firms coils and static machines, which, by suitable changes, can be made useful. What some of these changes are will be mentioned later. For physicians in the country, remote from electricity or waterpower, the problem is a difficult one. An attempt to solve this problem in several ways has been made for Dr. Williams, that he might be able to judge from observation what apparatus to recommend. The cheapest arrangement consists of a twelve-inch Ritchie coil, with the modifications shown in Plates 43, 44, Figures 79, 80, 81. The coil is excited from four storage cells, which are kept constantly charged by twenty-four gravity cells. This apparatus furnishes enough current to light an X-light tube for an hour a day, using forty-three watts in the primary and employing the hammer break usually furnished with the coil. Great attention must be paid to having the resistance of the tube such that this small amount of energy will be expended with the least waste. The plant requires no care except to renew the gravity cells at the end of from three to six months, according to the amount of time the light is used. The whole apparatus is enclosed in a case about the height and length of an ordinary bookcase, the coil being on top. An apparatus of this kind has been used for several weeks to test its value.[72] The construction is shown in Plate 45, Figure 82. The second form of apparatus is illustrated in Plate 46, Figure 83. It consists of a static machine driven by a one-horse-power gasoline engine, here placed near the influence machine for pictorial reasons, but which should be in a basement with only the belt

[72] Note added 1903. — Longer use showed the gravity cells were a weak element. A small gasoline engine and dynamo are better.

coming up through the floor. A quart of gasoline will run a medium-sized influence machine for an hour.[73] There are a few details in Plate 46, Figure 83, which should be mentioned. The stretcher first used by Dr. Williams at the Boston City Hospital is convenient for examining patients. The stretcher can be brought to the bedside, the patient being transferred to the X-light room with but little danger of fatigue. Hanging from the stretcher is a lead screen connected with the earth through a wire attached to a gas or water pipe. This arrangement of Dr. Williams is a modification of the Tesla screen and protects the physician not only from the effects of the ether strain, which may cause the painful burns we often see, but also from the X-light which Professor E. Thomson[74] and other distinguished electricians have stated is the cause of the burns. The third form of apparatus consists of the same gasoline engine driving a one-third horse-power dynamo, the current being used in one or more ways to excite a coil. First way, the dynamo is wound for one hundred and ten volts. The current is sent directly into the primary of the coil, being interrupted by a suitable break. This arrangement also requires the gasoline engine to be run while the patient is being examined. As the engine makes a noise, two other ways have been arranged which do not require the engine to be run at the time. First, the current is used to charge fifty storage cells enclosed in the same case shown in Plate

[73] Note added 1903. — Static machines need not be considered as sources of energy for exciting X-light tubes.

[74] Hawkes was the first to say X-light burnt. Refer to Note 136 A.

45, Figure 82. The charging can be done by a servant. The physician then has the means of exciting a coil for several hours a day without direct resort to moving machinery. The other way is to wind the dynamo for ten volts, charging four storage cells with the current, which may be used in the usual primary of a Ritchie coil, wound for that voltage. Any of these forms of apparatus can be assembled by the physician, as the parts are all commercially made. Whatever form of apparatus is adopted, and wherever it is used, the X-light tube must be in a non-radiable box, from which no X-light can escape, except the smallest cone of rays which will cover the area to be examined. In addition to the reasons already given there is another. X-light tubes burst suddenly without warning, throwing thousands of sharp fragments of glass in every direction. My eyesight would have been lost from this cause if from the beginning an enclosed tube had not been used. No one at present knows the cause of this bursting, which may occur at any time while the tube is excited or after the current has stopped. It occurs with tubes of different makers; in tubes having hydrogen, oxygen or water vapor regulators, as well as in those without regulators. In Note 87 it was shown that while a tube is excited, gas is being driven into the glass, combining with it to some extent. This may weaken the glass. — Electrical Review, December 19, 1900.

NOTE 112 continued. — X-LIGHT APPARATUS FOR PHYSICIANS IN THE COUNTRY AND OTHERS

In Plates 47 and 48, Figures 84 and 85, is shown a later form of tube-holder. It is provided with a spirit lamp. With this the tube can be made hot before exciting it, a matter of consequence for tubes without regulators when the initial resistance is high. The cover of the box is hinged, the sliding plate holding the Tesla screen and the diaphragm plate forming part of it. The box takes two as well as three terminal tubes. If, as nearly every one believes, X-light is responsible for the burns, then this is an important reason for always using an enclosed tube, for in this way the patient and physician are mostly protected from the light. In earlier notes all that seems at present necessary on the subject of tubes was said, and now generators will be considered, and the modifications which the commercial ones need to fit them for exciting X-light tubes for use with the cryptoscope, because the future of X-light in medical diagnosis lies largely in the results which will be obtained with this instrument. The first requisite is an apparatus which will give a powerful light under perfect control both in quality and intensity. To throw some light on this problem for Dr. Williams, the most powerful influence machine which has yet been constructed was made. This machine, which has sixteen plates averaging nearly two metres in diameter, has proved to be a satisfactory apparatus for producing X-light, and is a good generator for hospitals where cost and size are not important.[75] Constructing the machine at home, the cost, two thousand dollars, was probably greater than that of duplicating it. Messrs.

[75] Tubes excited by coils operated as recommended in Notes 159 and 163 can give steady X-light, and the apparatus is portable and powerful.

Oelling and Heinze believe this could be reduced to about seventeen hundred dollars. The floor space required for the machine is ten by six feet; the height ten feet. There is no other form of generator at present known that can compare with such a machine in the steadiness of the X-light from a tube excited by it, though it is hoped a modification of Trowbridge's storage system, which is being constructed, will equal it in this respect, as it would be more portable and less expensive, but greater attention to the resistance of the tube will be required, — refer to Note 99. The next most satisfactory generator is a coil which I designed for Dr. Williams. With it can be obtained all the various forms of currents used in electrotherapeutics and called by such odd names as "static induced," "faradic," "franklinic," "high frequency," and others. The coil gives a one-centimetre spark of small capacity, or a forty-three-centimetre spark of large capacity, or any potential between, by simply moving two handles within reach of the physician. This great flexibility in potential and amperage makes the coil useful for exciting X-light tubes, for the light is under control. A coil of this type is shown in Plates 49 and 50, Figures 86 and 87. The description begins with the primary. By means of two handles attached to this and placed within reach of the physician while making an examination or treating a patient, the output of the coil can be controlled by changing the position of the secondary in the field of ether strain produced by the primary. One handle causes the copper wire of the primary to vary its position in relation to the secondary. The other allows the core to be moved partly out, withdrawn, or another put in its place. Though familiar with similar adjustments in the feeble coils used in therapeutic work, one cannot appreciate the importance of these movements on a powerful coil both for X-light and electro-therapeutical purposes, except by actual observation.[76] The material of the tube separating the primary from the secondary is a matter of importance. It is desirable often to use fourteen hundred watts in the primary. With a powerful coil the current smashes through hard rubber and glass. Mica -micanite- is therefore better. The method of arranging the sections of the secondary differs from that in other coils. The sections are independent of the tube surrounding the primary. The tube may at any time be withdrawn to remove a section of the secondary. Each section is separated from the next by plates of micanite and can be removed by drawing out the tube enough to free it.[76A] The wires

[76] Note added 1903. — This feature has been abandoned by the firm who make this coil.

[76A] Note added 1904. — This method of constructing the secondary of a transformer has been condemned; one writer saying there was "no excuse for such a makeshift as this," while another has stated that the method of construction had proved to be defective. Having built both open and closed circuit transformers on this plan and found them excellent, on deciding to reprint some of these notes inquiry was made of the Heinze Manufacturing Company in regard to their experience in making coils containing this principle of having the sections of the secondary independent of each other and of the tube separating them from the primary, thus allowing repairs to be quickly made as extra sections could be kept ready. Their reply stated they had made about eight hundred coils, having spark-from every seventh pair of sections are brought up to a brass ball in a glass or mica plate extending the length of the coil. By means of the adjusting rods shown in Plates 49 and 50, Figures 86 and 87, any number of sections of the secondary from seven to ninety-six can be used. To vary the amperage with any of these degrees of potential the movements of the primary already mentioned suffice. It is interesting to see the output of the coil reduced by these means from a roaring torrent capable of killing a man to a little spark hardly felt when the current passes through the body. By removing the caps of the Leyden jars, putting in their places hard rubber rings supporting the high-frequency coil, we get this form of current for therapeutic work, and adapt the coil to a very important future field of electricity in medicine.[77] With the electrolytic break invented by Spottiswoode in 1865 and familiar to those who have studied the early literature of vacuum-tube work a large amount of current can be sent through the primary of a coil. As a result the resistance of tubes soon falls, the light in consequence becoming of a character that does not properly illuminate the fluorescent screen. To overcome this a spark-gap is used in series with a tube, answering the purpose

lengths from twelve to fifty inches, all of which were giving satisfaction. The following illustration of the simplicity of the method is mentioned. The directions contained in Note 137 for constructing a seventy-centimetre coil were given to a man without mechanical training who was over forty years old and had always worked on a farm. He built a satisfactory coil which had the spark-length equal to that given in the directions.

[77] Refer to Note 179 B for details.

roughly for a time. As the resistance continues to fall, the spark-gap must be made longer to keep the character of the light constant. It becomes too unsteady to be suitable for the cryptoscope. The same difficulty is also encountered with a powerful static machine. To overcome it multiple spark-gaps must be used. Consult here Notes 45 and 72. It is difficult to learn who first used more than two spark-gaps in series with an X-light tube. The idea came to me through Mr. Nado Soracio, who used three. The number was increased to fourteen on the static machine shown in Plate 46, Figure 83. For a generator of this size, however, the double adjustable spark-gap shown in a note in the American X-ray Journal for November, 1898, and in Plate 46, Figure 83, answers, as such an apparatus has neither the potential nor amperage, to use tubes of as low resistance as are desirable to get the best light. Williams applied the idea of several series spark-gaps which we obtained from Soracio to his large static machine. The form he used was shown in the Scientific American for June 17, 1899. His construction was applied to the static machine mentioned in Note 39, the spark-gaps being enclosed to prevent noise. When so enclosed, the hard rubber took fire, becoming a good conductor, short circuiting the spark-gaps. A glass tube was then used, the balls being fastened into holes drilled in the glass. When glass is drilled it is apt afterward to break. This form was abandoned, the balls being supported by encircling rings. It was efficient, but too expensive. The balls were next mounted on strips of mica, the strips being enclosed in boxes of prepared wood. Plate 43, Figures 79 and 80 were then made of the arrangement, as it appeared to be satisfactory. After a time the spark began to jump to the wood, at length carbonizing it, short circuiting the spark-gaps. Next the plan shown in Plates 44, 48, 49, 50, Figures 81, 85, 86, 87, was adopted.[78] It is efficient, cheap, easily applied to any of the usual types of generators in the market. The strips of mica carrying brass balls are enclosed in glass tubes,[79] closed at one end by caps of hard rubber provided with brass balls projecting into the tubes and serving as the terminals for the coil. The other ends of the glass tubes are closed by metal caps provided with metal sleeves through which pass sliding brass rods terminating at their inner ends in brass balls, at their others in non-conducting handles. The figures -81 and 85- show this arrangement attached to a Ritchie coil. This coil has been selected for illustration because we owe to Ritchie the modern type of induction coil. Page invented the induction coil, developing it from the discoveries of Faraday, Henry, Sturgeon. Ritchie[80] invented the method of winding the primary in sections, which is used by every maker. It was four years after Page's coils were in use before Ruhmkorff made one as good, therefore induction coils, if they are to bear the name of any man, should have the names of Page and Ritchie.[81] To adapt a Ritchie coil for work with the fluoroscope the

[78] For improvements refer to Note 179 D.

[79] Mica tubes are better because opaque. If glass is used, it should be made opaque.

[80] Note added 1903. — Poggendorff was the first to use this method -A History of Physics, Cajori-.

[81] Poggendorff, not Ritchie.

ordinary terminals are removed, new supports being attached, ending in sockets into which metal balls of various sizes may be set in order to vary the capacity to suit the requirements of the tube. The multiple spark-gaps are supported from the usual hard rubber ends of the coil by posts of hard rubber terminating in rings of the same material.

These rings support the glass tubes forming the exterior of the spark-gaps. When the brass rods are pushed into the tubes, they make contact with the balls forming the terminals of the coil. The current comes through the rods to the tubes by the flexible connecting wires. One or more spark-gaps may at any time be introduced by drawing out the rods. The current must then jump from one ball to another, the number being determined by the position of the rods. There are many Ritchie coils in use, and it is to be hoped the owners will apply this form of spark-gap to them. Plates 49 and 50, Figures 86 and 87, show the method used on the variable-potential coil. The handles controlling the spark-gaps are in convenient positions for the physician to operate them, thus controlling the light, without removing his eyes from the fluoroscope. This is a matter of prime importance. It is the custom to think high potentials are not desirable for X-light, that generators having six-inch sparks are sufficient, because tubes give the best light when they have a resistance of from two to four inches. Nevertheless, there is a great objection to such generators as already mentioned in earlier notes. One objection is now repeated. The amount of force sent into a tube to produce a strong light drives many particles into the circulation. The result of this increasing mist through which the cathode stream must force its way to the target to produce X-light is to cause the stream to strike with less force. Less X-light is therefore produced than under more favorable conditions, and finally none can be obtained. The tube must be repumped or run for many hours until the particles have been driven into the glass, thus raising the resistance to the proper point for producing the light with the least expenditure of force. If the tube is attached to a generator of sufficient potential to allow the use of many spark-gaps in series, the low-resistance tube can be made to give an abundance of light of a beautiful quality for fluoroscopic work or for photography. This matter is illustrated in Plate 51, Figures 88 and 89. The subject was a piece of a hen. The negative from which Plate 51, Figure 88, was made had an exposure of twenty-eight minutes with a low-resistance tube and no spark-gap. The negative from which Plate 51, Figure 89, was made was exposed twenty-eight seconds with multiple spark-gaps in series. The plates were taken from the same box, exposed at the same distance from the tube, which had remained excited during the interval between the exposures, a period of two minutes. The tube had been excited continuously for three hours to get it into a fairly constant state. The only change in the conditions was the introduction of spark-gaps when the second plate was exposed. The plates were developed together in the same solution for the same time. Though the first had sixty times the exposure of the second, no trace of an image was visible, the negative developing as clear glass and therefore printing black as in the figure. The result would have been the same had the exposure been twenty-eight hours instead of minutes, for the tube was giving no X-light without spark-gaps. In this connection it should be stated a tube may not be giving any light visible in the cryptoscope and yet it may be capable of producing an image on a photographic plate, which, as well as other experiments, shows how important it is to find new fluorescent substances. No better illustration of the value of high-potential generators should be required than these two pictures. If other proof is needed it may be found in the greater ease with which Dr. Williams has been able to continue his classical work at the Boston City Hospital since experiments showed to us the importance of high-potential generators and low-resistance tubes -that is, tubes so low as to be considered useless by others-, for obtaining a light under perfect control and having the proper quality to differentiate markedly tissues differing but little in density. Refer to Note 10, Electrical Review for January 5, 1898, where the matter was treated from a different point of view.[82]

Some one may ask why not insist upon obtaining from the makers tubes with stable resistances of the degree fitted for low-potential generators. Aside from what has already been said there is another reason. The terminals of

[82] Refer to Note 152 for methods of using an automatic regulator for controlling the quality of X-light without removing the eyes from the image on the fluorescent screen.

such tubes are very dry. The sources of the cathode stream being partly dried up, the use of a regulator to bring fresh gas into the tube is sooner required, or the tube must be heated. A tube that when run for an hour has no measurable air resistance, meaning by this one with less than a millimetre, is very convenient. With such a tube we have the means of sweeping through a great range in the character of the light by simply moving the spark-gap and the potential handles of the coil. In this way bright light may be suddenly evolved from intense darkness. The coil was made from my designs by Oelling & Heinze, to aid Dr. Williams in his work at the Boston City Hospital. For interrupting the current in the primary the Heinze break made by the same firm may be used. This is a modification of the Spottiswoode break already referred to. This break has been subjected at intervals to the roughest use in experiments during the past year.[82A] Its general form is evident from Plate 52, Figure 90. By means of a motor, one or more platinum wires are caused to move in and out through orifices in glass tubes under proper solutions. This is the only commercial electrolytic break which gives a sufficiently steady light for use with the cryptoscope. No break gives quite as steady a light as a powerful static machine.[83] — Electrical Review, December 26, 1900.

[82A] Note added 1904. — Mr. John O. Heinze has invented a mechanical break superior to his electrolytic type. With this break and a fifty-one-centimetre coil of the type here illustrated photographs of adult hips can be taken in a few seconds, and instantaneous exposures are sufficient for the chest.

[83] Breaks are not necessary. Refer to Notes 159 and 163.

NOTE 113 — THE VACUUM IN AN X-LIGHT TUBE

That the vacuum in an X-light tube must be in the neighborhood of a millionth of an atmosphere is a fetich worshipped too long. That the "dark space" must fill the tube before X-light can be produced is an error. That a free path — the so-called "free molecular path" — is required is absurd. There is no proof of the existence of such a path. It is not entirely the vacuum that determines the fitness of a tube. It is the condition of the terminals and the generator. If there was energy enough, the cathode stream units could be rushed through a tube at atmospheric pressure, producing brilliant X-light. Selective filters should be used to strain out these vibrations whose period causes them to suffer most diffusion in the tissues, thus blurring the image of deep-seated tissues.

Electrical Review, January 5, 1901.

NOTE 114 — ON BALANCED CATHODES

In earlier notes it was shown cathodes lost in weight, some losing more than others with the same amount of electricity. As this is a point of theoretical importance, a figure of one of the tubes used is given in Plate 53. The cathode is made one arm of a balance.

Electrical Review, February 2, 1901.

NOTE 115 — CATHODES OF RADIO-ACTIVE SUBSTANCES

A tube, Plate 54, Figure 92, was made with an aluminum cathode, whose edge was turned up to act as a rim, to prevent the layer of radio-active material from falling off the surface of the cathode, which it covered to the depth of two millimetres. The target, of platinum, was made with a hinge, to allow it to be turned out of the way, enabling the radiations to pass unimpeded through the tube to the thin wall opposite the cathode, beyond which was placed the photographic plate. Before exhausting the tube a plate was exposed. The tube was then exhausted by heat and heavy surges until no current could be made to pass through it. Another plate was exposed to the radiation. The power of the radiations was increased.[84]

Electrical Review, February 2, 1901.

NOTE 116 — A SMALLER SEEHEAR

In a larger form with an open screen this instrument was figured in this journal for February 8, 1899.[85] The instrument contained two principles new in stethoscopes: one a sound chamber, the other a fluorescent screen in connection with a sound chamber. The former has since been adopted in one of the stethoscopes in common use. The latter awaits recognition. As shown in the figure, the fluorescent screen is about seven centimetres in diameter. The sound chamber is one centimetre in depth, the wall toward the patient being of thin hard rubber or other radiable material. There is an advantage

[84] This experiment was carried on for me by Mr. J. O. Heinze, Jr., during the summer. More experiments should be made. After this the radium salt was kept in a purposely exhausted X-light tube to see if the tube could be regenerated from the particles sent off, some of which might be similar to those used up in the working of the X-light tube. Refer also to a footnote to Note 175.

[85] Refer to Note 47.

in hearing the sounds in the chest while the organs are under inspection, and as comparatively cheap apparatus, giving plenty of X-light of suitable quality, is now obtainable, such an instrument as the seehear should be used more extensively than it has been. Perhaps in the form now shown it may be more appreciated.

Electrical Review, February 2, 1901.

NOTE 116 B—ON AN X-LIGHT EXAMINATION TABLE

With a coil like that shown in Plates 49 and 50, Figures 86 and 87, Note 112, it is necessary to be able to move the patient in a line parallel with the long axis of the coil, instead of moving the tube, to enable the physician readily to reach the spark-gap handles to control the light without removing his eyes from the fluoroscope. For this and other reasons a different arrangement from Dr. Williams' stretcher shown in Plate 46, Figure 83, Note 112, should be used. Plate 56, Figure 95, illustrates an X-light table on wheels which allow it to be easily rolled to bring any part of the patient between the tube and the physician's eyes without his moving. A strong frame of hard wood has a table, two hundred and twenty-eight centimetres long by sixty-six centimetres wide, pivoted in its centre, to enable it to be tipped, a movement of importance in certain examinations. If a patient with stone in the bladder is placed with his head lower than his feet, the stone in a distended bladder falls away from the shadow of the pelvis, coming so near the wall of the abdomen and the photographic plate a sharp picture may be made, if light of long waves is used, such as may be obtained in sufficient quantity with a powerful generator and a tube of low resistance giving no X-light without multiple spark-gaps or some of the other means mentioned in earlier notes for regulating the surges. If the X-light tube is to be below the patient, the handles of the stretcher on which he is brought to the X-light room are to be placed in the notched end-pieces. Any part of the thin top of the table may then be removed to avoid loss of light, though this is small, as the top is made of thin cross-glued veneers. The under side of the veneers is coated with aluminum paint, serving when grounded as a Tesla screen.[86] If the plate is to be placed below the patient, the tube being above, he need not be disturbed, for one end of the stretcher may be lifted enough to slide the plate-holder between the canvas and the top of the table which may be replaced for the purpose of supporting the plate.— Electrical Review, March 9, 1901.

NOTE 116 C — PRECAUTIONS AGAINST DIFFUSED X-LIGHT

A plate should as far as possible be protected from all X-light except the direct rays coming through that part of the object being photographed. To accomplish this, several precautions should be taken. First, the tube should be in a non-radiable box from which no X-light can escape except the smallest cone of rays that will cover the area to be photographed. Such a box and support were shown in Plates 12, 21, 31, 38, 45, 46, 47, 48, Figures 34, 48, 60, 73, 82,

[86] Refer to Note 136 B in regard to screens.

83, 84, 85.[87] For use with the coil and table illustrated in Plate 56, Figure 95, the tube requires to be moved in but three ways, vertically, antero-posteriorly, and in vertical arc. As no movement in horizontal arc is desirable, the round tube of Plate 38, Figure 73, was replaced by a square one. The ball bearings of B, Plate 38, Figure 73, were dispensed with to save expense. The arm, Plate 57, Figure 96, carrying the tube-box, was graduated into centimetres on each side of a zero. When the zero-mark is opposite the pointer, the patient's medial line should be in the vertical plane passing through the radiant area of the target of the X-light tube. The object of the graduations was to tell quickly how far the radiant area was moved in taking stereoscopic negatives or two photographs of the body on the same plate from different positions.

Second, The plate should be placed in a metal case[88] with a radiable front and non-radiable back and sides, that the only light to reach the plate may be the X-light shining through the object being photographed. As the plate-holder must often be below the patient, it should be arranged to bear his weight without the plate being injured, and should protect it from perspiration. The holder ought to be thin to be comfortable to lie on. Therefore the usual form of photographic plate-holder was discarded, the X-light plate-holder being made of metal in two pieces. One was a frame of brass two centimetres wide by four millimetres thick, to which was attached, light-tight, a thin sheet of aluminum.

[87] Note added 1903. — A more elaborate form of this apparatus is shown in Notes 143, 148, 149, 151, 155, 156.

[88] Illustrated in Note 121.

The other was a plate of brass three millimetres thick with a rim to act as a lightlock. Inside the rim there was a strip of velvet. When the two pieces were brought together, the velvet served in connection with the rim to exclude the light except the X-light coming through the aluminum front. The plate-holder was held together by clamps like those of pocket-books. Unexposed plates should be kept in triple lead boxes made on the plan of the pasteboard ones in which they come, for the X-light from a powerful generator readily enters through cracks.

Third, Strips of cloth coated with white lead mixed with oil and soap to keep it pliable are to be laid on the top of the table, the ends hanging over.[89] An opening is left to allow the cone of X-light from the tube to pass through. When the patient is in position these strips are brought up over him, before the photograph is made.

Electrical Review, March 9, 1901.

NOTE 117—WHERE WAS THE X-LIGHT TUBE WHEN THE PHOTOGRAPH WAS MADE?

In looking at an X-light negative it is necessary to know where the tube was in relation to the negative. As far as possible the record should be automatic and recorded on the plate. An instrument shown in Plate 56, Figure 95, at LW, is convenient. It consists of a small metal wire attached to the radiable middle portion of the Tesla screen. If the long axis of this wire forms a straight line, as it should, between the radiant area on the target and the negative, it will appear as a round spot. If otherwise, as a

[89] For formulæ for non-radiable coatings refer to Note 173.

line whose length and direction give valuable information as to the position of the tube.[90]

Electrical Review, March 9, 1901.

NOTE 118 — CATHODES FOR POWERFUL SURGES

In a former note it was said the size of a cathode should be in proportion to the size of the surges. The coil spoken of in Note 112 clearly established the importance of this principle. Since then a more powerful coil of the same type has again shown the truth of this, and another statement made; namely, the way to distinguish between tissues differing but little in density was to get enough light of long waves. The usual generators are almost useless for fluoroscopic examinations of the thick parts of the body, for to get sufficient light, the tube must have a high resistance, and such light penetrates the bones about as well as the soft tissues. No great advance will be made in medical diagnosis with the fluoroscope until the use of powerful apparatus is more common, and then physicians will be brought face to face with the problem of the next note.

Electrical Review, March 9, 1901.[91]

NOTE 119 — THE GREATEST PROBLEM IN X-LIGHT TUBES

Every time a more powerful generator is made the increasing importance of finding the

[90] Refer to Notes 143, 148, 150, 155, 156, where this plan is shown embodied in convenient instruments.

[91] Refer to Notes 32, 94, and later notes for correct method of using X-light with the cryptoscope.

best way of curing tubes suffering from terminal exhaustion is seen, for the disease makes its appearance earlier and is about as hopeless as chronic anæmia in man. In former notes the opinion was advanced that we depended on gas amalgamated with the terminals for producing an efficient cathode stream and X-light, and it was shown, while by introducing oxygen or hydrogen or nitrogen we could permanently lower the vacuum, the ability to form an efficient cathode stream and X-light continued to diminish. Some suggestions were offered for remedying the difficulty, but simpler and better ones are needed. This problem should be solved, for few discoveries could aid more in the relief of human suffering than this, as it would enable a physician always to have an abundance of X-light of proper wave-length without more trouble than the turning on of an incandescent lamp. One direction in which to work is to try to find the new gases it was suggested might be the cause of the pristine brilliancy of an X-light tube. Having found them, the problem would be how to introduce them easily in proper amounts. A second possible direction is to look for substances, not gases, in the metals of the terminals, which have the properties attributed to radium of giving off minute particles, the supposition being if a cathode could be alloyed with them the great stress in a vacuum tube might cause them to be driven against the target with sufficient force to produce X-light.

Electrical Review, March 9, 1901.

NOTE 120 — THE ECONOMICS OF THE X-LIGHT TUBE[92]

A properly prepared X-light tube deteriorates in use. No practical means for preventing this are known, though vacuum regulators which introduce fresh gas into the tube are supposed to accomplish the result. What is the cause of the phenomena and what the remedies? Any theory which will serve as a working hypothesis is better than none. To produce X-light we depend upon gases amalgamated with the metal terminals in a vacuum tube. These particles are driven by the electric current from the cathode against the target, where they are heated to such a high degree as to become radiant centres from which X-light arises. The higher the velocity of impact, the greater the temperature and the more penetrating the light. On this theory the process of "pumping" a tube does not consist in simply removing the air, but is twofold. Enough air must be taken out to allow the gas particles shot from the metal of the cathode by the electric current to have a comparatively free path on their way to the target. So much gas must be driven, by electricity, from the metal of the terminals, the electric stress will not make it come out too fast when the tube is used. The effect of producing X-light according to this theory is necessarily to bring out these gases. If they did not come out and we depended upon the air in circulation in a tube, there would not

[92] This note was published in a different journal from that in which most of the others were printed, and was intended as a grouping of some previous statements. It may therefore be passed over if the other notes have been read.

be an efficient cathode stream and sharp definition. The first effect of use, then, is to lower the vacuum in an X-light tube. As a result, the particles forming the cathode stream meet with more obstruction from the increased density of the mist filling the tube, through which they must force their way to the target, consequently they strike with less velocity, are heated to a less degree, giving rise to an unsuitable kind of light. By means of a reservoir and movable dam, outside the tube, the current may be held back and sent in powerful surges which impart a higher initial velocity to the cathode stream particles, causing them to strike the target at a sufficient velocity. After a time the continued formation of a cathode stream so reduces the number of particles in the metal, the current finds more difficulty in passing, charging each particle therefore to a higher degree, producing in it a higher velocity and causing it to strike the target harder, the resulting light becoming of more penetrating character. This is the explanation of the second stage, the advancement to the third state being hastened by the absorption of the cathode stream particles by the glass walls of the tube. The third state is but a continuation. The particles have still further diminished in number — those remaining are more tightly held by the metal — the current cannot separate them unless the potential is increased: the tube gives no light, for no current is sent by means of the cathode stream. What is the remedy? The one in universal use is to introduce gas into the tube. Crookes recommended water vapor. In earlier notes formulæ were given for chemicals which liberated oxygen or nitrogen, but finding the cathode stream spectrum was chiefly from hydrogen, directions were given for introducing this gas, expecting it would be the ideal regulator, but more powerful generators showed introducing it did not at once restore the pristine brilliancy of a tube. No common gas put into a tube will permit it to continue to give a satisfactory light with the expenditure of a reasonable amount of power. The effect of introducing more gas is to increase the density of the mist through which the cathode stream must force its way. When the particles move too rapidly, as in a high-resistance tube, where no gas has been introduced, the introduction of gas retards them and alters the character of the light, but the effect is temporary. We need to do something different; namely, to restore the same kind of gas to the metal of the cathode as has been used up in making the cathode stream. In earlier papers various methods for doing this imperfectly were given. The chief problem of X-light tubes is to find the ideal way. Until the problem is solved, generators should be constructed to conserve the supply. They should also be made to give high potentials, that an external reservoir may be used to hold back the current and send it in powerful surges when, as in a new tube, the mist is increased by the cathode stream, or in an old tube by introducing more gas than was intended. The importance of this is well shown in Plate 50, Figure 87, Electrical Review for December 26, 1900. The negative had an exposure of twenty-eight minutes without such a reservoir and dam, the plate not being acted on; while in Plate 51, Figure 88, the use of a reservoir and dam produced a good picture with the same tube in twenty-eight seconds.

To economize the supply of gas in the metal the surges should be of the shortest possible duration and yet of sufficient volume to produce the required light. The tube should then rest, until to make the light continuous to the eye, another surge must be sent. Twelve hundred surges a minute are enough. The volume of each should be several horse-power if we wish to advance rapidly in the differentiation of tissues in the thick parts of the body with the cryptoscope. In attempting to work in this direction with static machines, even the most powerful, constructed for the experiments, had neither potential nor amperage enough, though the plates averaged two metres in diameter and weighed over a ton. For the present, coils are better, but the insulation should be more perfect, for those in use are quickly spoiled by less powerful surges than it is desirable to use. Micanite is the only material suitable for insulation between the primary and the secondary. Thanks are due to the Micanite Company for their co-operation, for without it, experiments with heavy surges would have been abandoned, until Trowbridge placed his generator within reach. As the duration of a surge may depend upon the break, it is of importance to improve this. Only some modification of the electrolytic break of Spottiswoode -1876- will bear powerful surges without rapidly deteriorating. One of the breaks designed on this principle is shown -Plate 58, Figure 8-.[93] It consists of a covered

[93] Where the coil is excited without a break as recommended in other notes rapid surges can be obtained by

tank containing an electrolyte. Two platinum arms are caused to revolve in such position one of them may dip into the solution once during each revolution. The second arm does not touch the liquid, its object being to act as a balance. If the shaft makes fourteen hundred revolutions a minute, the duration of a surge is but a twenty-thousandth of a minute. It may be further reduced in several ways. The solution may be lifted into a tank and discharged from an orifice against the arm. Or a second break may be introduced into the circuit, the time of the immersion of the platinum not exactly corresponding with that of the first break. The effect is to deliver current to the first break during only a part of the time it is immersed.

Before closing this paper attention is called to an experiment by Trowbridge in 1898. By means of a Plante generator of his own design and construction he obtained a photograph of the bones of the hand in a millionth of a second. In doing this he placed the mark so high few have seen it, and no arrow has approached it. The experiment was of the deepest significance, encouraging me to go on experimenting with higher potentials for producing X-light.

Conclusion. — The most important discovery to be made in X-light tubes is to find how to keep the character of the light constant. Meanwhile the best way to excite an X-light tube for cryptoscopic examinations is to use surges of millions of volts and many horse-power, each surge lasting for not more than a millionth of a second.

Boston Medical and Surgical Journal, Volume 144, Number 17.

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suitable capacity methods. Trowbridge obtained such surges with a Plante machine.

NOTE 121 — AN X-LIGHT PLATE-HOLDER

There are two methods in use for protecting sensitive plates in making photographs by X-light. The plates are wrapped in colored paper, or the ordinary wooden photographic plate-holders are used. Both methods are undesirable, for an X-light tube fills a room with a bright though invisible light, which, dashing about in every direction, fogs the plate or makes images on it of objects on the opposite side from the body being photographed. No X-light should reach a plate except what comes through the patient being photographed. A first requisite in an X-light plate-holder is a means to achieve this; second, the plate-holder should bear the weight of a patient without risk to the plate, even though it is necessary for him to sit on it; third, it should be thin, to avoid discomfort to the patient when he lies on it; fourth, it should be moisture proof, to protect the plate from perspiration. For several years metal plate-holders which meet these and other requirements have been used in these experiments. The latest and simplest plate-holder is shown in the figures. Its total thickness is seven millimetres. There are two pieces, a back of non-radiable, a front of radiable metal, aluminum, held together by steel clamps. A support for the holder was shown in Plate 56, Figure 95, illustrating an X-light table in a former note. Another support attached to the upright shown in Plate 56, Figure 95, is illustrated in Plate 59, Figure 6.

Boston Medical and Surgical Journal, April 25, 1901.

NOTE 122—REMOVING THE IRRITATING GASES PRODUCED BY X-LIGHT GENERATORS

A powerful X-light generator produces ozone and combinations of nitrogen and oxygen. These are irritating to the respiratory mucous membranes. A fan should be placed within the case of a static machine to drive the gases into the nearest chimney. A coil should have the spark-gaps enclosed, as shown in Note 112, the gases being drawn by an aspirator into the waste water pipes.

Boston Medical and Surgical Journal, April 25, 1901.

NOTE 123—X-LIGHT CAN KILL ANIMALS

In the Electrical Review for January 5, 1898, it was stated that the so-called X-light burn could be produced by electricity when no X-light was present. Here it will be shown when electricity is excluded, death can be produced by X-light without burning. A strong male guinea pig was placed in a grounded Faraday chamber and exposed to X-light for two hours a day, the source of light being outside. He died on the eleventh day. The experiment was repeated, with death on the eighth day. No burns in either case. There were many details connected with these experiments which are not given, remembering how many hours of sunlight have been lost through being obliged to read long papers. An attempt will be made to get this note printed in a medical instead of a physical journal, where the others of the series have appeared: First, Because the experiments separated the effects of electricity from those of

X-light and showed clearly what a powerful agent X-light was. Second, To call attention to need of using this power in new growths in the interior of the body. Third, To give an opportunity to repeat three precautions: -A- the physician in using the fluoroscope should wear glasses of the most non-radiable material that is transparent; -B- the X-light tube should be in a non-radiable box from which no X-light can escape except the smallest cone of rays which will cover the area to be examined, treated or photographed; -C- the patient should be covered with a non-radiable material, exposing only the necessary area.

Boston Medical and Surgical Journal, February 14, 1901.

NOTE 124 — NOTES ON X-LIGHT

A pregnant guinea pig was placed in a closed metallic chamber hung by silk cords within a closed metallic chamber connected with the ground. This is the same arrangement for excluding electricity as a factor in the results which was used in the other experiments. The source of X-light was outside. Exposure to X-light killed the fœtus. The statement of these experiments is limited to one guinea pig, and this note is published because pregnant women are being exposed to X-light to determine the size of the pelvis or to examine the condition of the fœtus. A woman has been known to abort after exposure to X-light. What people fear is uncertainty; therefore, when a new agent is employed in medicine it is important to determine its power by experiment on animals. When the worst is known and the agent under control, we need not fear patients will object to its use.

Nothing is gained by criticising such experiments, for criticism is sterile, while experiment is fertile. An experiment can only be discredited by another experiment.

Boston Medical and Surgical Journal, February 28, 1901.

NOTE 126—NOTES ON X-LIGHT: THE CONTROL GUINEA PIGS

In this journal for February 14 it was shown X-light could kill animals. That an invisible radiation of which none of our senses make us conscious should be able to produce death, leaving no sign to the eye, is one of the most remarkable facts in the domain of medicine, and full of promise for therapeutics. These experiments were published chiefly because: in them for the first time the participation of electricity in the results was certainly excluded; they were the first that proved X-light could act below the surface of the body; they showed X-light had the power to affect profoundly the life processes. As the experiments have been doubted, the deaths being attributed to other causes, the condition of the control guinea pigs is reported. These were kept in the same pen with those exposed to X-light. All were given the same food and care. Some of the control guinea pigs gave birth to young that have now reached the adult stage. No death or visible sickness has occurred except in those exposed to X-light. If activity, appetite, fine coats and bright eyes are signs of health, these control animals are well. The chief object in these investigations was this: A friend had been operated on for cancer. As no second operation would have been practical, it was desirable to know whether X-light could be used to affect cell growth in the interior of the body; and if it could, whether the results could be accomplished without danger of burning. The experiments suggested that internal cancers beyond the reach of the knife might be favorably affected by X-light.

Boston Medical and Surgical Journal, March 28, 1901.

NOTE 128 — EXCITING X-LIGHT TUBES

The object of this paper is to show why high-frequency currents are not at present very suitable for exciting vacuum tubes for the production of X-light for diagnosis. We depend upon gas amalgamated with the terminals of the vacuum tube to form an efficient cathode stream for producing X-light. The available supply of gas is limited. When it is exhausted the tube is not valuable, because there is no practical means of restoring the gas. Therefore, the best generator for exciting an X-light tube is one which uses the supply of gas most economically, producing most X-light from the least gas. There are two types of generators in common use, — those giving a so-called unidirectional current -induction coils and static machines-, and those giving an alternating current -Tesla or high-frequency coils-. There are several reasons why the latter are more unsuitable. With the former the cathode is always supposed to be a cathode,[94] but with the latter the cathode is half the time an anode. When the normal cathode is acting as an anode, all the gas which is removed to convey the current is wasted, none of it producing available X-light. The gas is

[94] Note 17.

more rapidly removed from an anode than from a cathode. During the time, therefore, when a high-frequency apparatus is used to excite an X-light tube the gas is not only wasted, but the rate of waste is high. With powerful high-frequency generators the terminals are rapidly robbed of their gas. The electricity, finding insufficient means of conveyance by convection over the space of strained ether between the terminals, heats the metal of the cathode, which in consequence is melted, the tube becoming useless.

Double-focus tubes are generally used for alternating currents. In these tubes the target, which is the metal surface on which the cathode streams strike and from which X-light arises, is not connected with either pole of the generator. It is an independent piece of platinum placed midway between two concave aluminum terminals, which are alternately positive and negative. Single-focus tubes only are required for unidirectional currents. In these tubes the target may be an anode. A target which is an anode is a more efficient source of X-light, because the particles of the cathode stream strike an anode at a higher velocity than they do a surface of metal placed in their path which is not an anode; because having charges of opposite sign an anode attracts them.[95] Velocity of impact is of prime importance in an X-light tube, because the higher it is, the greater the temperature to which the particles are raised, and the larger the proportion of X-light to common light in the resulting radiation. Double-focus tubes are more expensive to construct.

[95] Consult Note 31 for the principle on which a tube can be made efficient without the target being an anode.

They are more subject to accidents than single-focus tubes. It is more difficult to obtain good definition from a double-focus tube because there are two areas on the target from which X-light arises.[96] Before alternating currents can be made suitable for exciting X-light tubes some more convenient means of rectifying the current must be found, and the surges should be under better control.[97] As such generators require less wire for equal potentials, they are cheaper to build, and attempts should be made to adapt them. The surges follow each other with great rapidity. As each surge removes gas from the terminals, the available supply is more rapidly exhausted than with a unidirectional current, where the duration of each surge and the intervals between can be regulated. Until we learn to restore easily the gas to the metal, unidirectional currents are to be preferred. The potential should be high. Seven million volts would be superior to a less potential. The current surges should be of the least possible duration, — a millionth of a second. The size of each surge should be the least that will give a sufficient amount of X-light for use with the cryptoscope. The intervals should be the longest compatible with an apparently continuous light, or about a twelve-hundredth of a minute, for each is a period of rest to the tube during which the supply of gas in the metal is not diminished.

[96] Consult Note 168 for method of using double-focus tubes in therapeutics. Consult Note 17 for a description of a tube which can give good definition with alternating currents.

[97] Refer to Notes 159 and 163 for means of making the surges more regular.

To operate a tube in this manner, the greatest attention is to be paid to the designing of the device for breaking the current. A rapidly revolving arm, which allowed the current to pass by dipping into an electrolyte once during each revolution, was found to be a good method.[98] In this way the duration of a surge was easily reduced to less than one-fourteenth of the period of rest. By placing two of these instruments in series, so the second sent the current during only a part of the time that the arm of the first was immersed in the electrolyte, the duration of a surge was still further shortened.[99]

Electrical Review, June 1, 1901.

NOTE 129—THE GASES OF THE CATHODE STREAM

As one object in writing these notes has been to make suggestions which might be of use to those who make or use X-light tubes, some recent advances in physics will be mentioned which should be considered when attempting to improve the present forms of apparatus. In previous notes frequent mention was made of the important part played by hydrogen in the production of X-light. The presence of this gas was determined by its spectrum in the cathode stream and in the gas recovered from the walls of X-light tubes after long use, but Trowbridge has since shown, in the course of some great experiments, accounts of which have been published in the American Journal of Science and

[98] Refer to Note 120.

[99] Where no break is used, the surges are readily obtained by holding back the high-potential current, discharging it at suitable times.

Philosophical Magazine, that what had always been considered a pure hydrogen spectrum cannot be produced unless water vapor is present; therefore, in many cases where hydrogen was mentioned, oxygen must have been present also to produce the spectrum. This bears in various ways on the construction of X-light tubes.

Electrical Review, November 30, 1901.

NOTE 130 — THE GASES IN THE TERMINALS OF X-LIGHT TUBES

By the light of Trowbridge's experiments the work with platinum and palladium cathodes has been repeated. It is known these metals do not readily combine with gases, though they occlude them. Their want of efficiency as cathodes may be partly due to the gases being so lightly held by the metal that they are soon given off. In the case of metals like aluminum and magnesium, which have a greater tendency to combine with gases, these are more firmly held, and for this bond the term amalgamation has been suggested in earlier notes. On account of the firmer nature of this bond, these metals may act as more lasting storehouses of gas and make the life of the tube longer than when the cathodes are made of platinum or palladium. The common gas for which, under ordinary circumstances, magnesium and aluminum have the greatest affinity is oxygen. As this makes a good temporary reviver for an old X-light tube, and as its presence in the cathode stream is said by Trowbridge to be essential to produce the spectrum I found there and attributed to hydrogen, amalgamated oxygen may be an important source of the particles which continue to produce the cathode stream after a tube has been in use for hours. As Weichert has shown the cathode stream particles have only a thousandth of the mass of hydrogen atoms, the source mentioned would seem sufficient, although the proportion of gas to the whole mass of the cathode is small. — Electrical Review, November 30, 1901.

NOTE 131 — FOCUS OF THE CATHODE STREAM

In Note 1., December 1, 1897; Note 2, December 15, 1897; Note 6, December 22, 1897, it was shown the focus of the cathode stream varied in distance from the cathode according to the conditions of the tube, reasons for the phenomenon being given. In Notes 4 and 20, tubes were shown in which the distance between the cathode and target could be varied in order to keep the focus of the cathode stream on the target, it having been proved in Note -1.- this was necessary to insure sharp definition. With the powerful generators, such as seventy-six-centimetre coils, excited by electrolytic breaks, which are now coming into the hands of physicians, the resistance of an X-light tube is quickly lowered unless too much of the life of the tube is sacrificed in pumping. As a result the definition becomes poor, because the focus of the cathode stream draws up toward the cathode. To restore the definition it is necessary to bring up the target to the focus.

Electrical Review, November 30, 1901.

NOTE 132 — INCREASING THE SIZE OF THE CATHODE

In former notes it was repeatedly pointed out "that the size of the cathode should be in proportion to the size of the surges." The surges, in the case of the most recent apparatus, when the coil is arranged for cryptoscopic examinations, are so large the cathodes have reached a diameter of fifty-six millimetres for coils giving fifty-six-centimetre discharges. A cathode of this size is difficult to insert into a tube; and for the full benefit to be derived from stronger currents and higher potentials, cathodes must be larger. Therefore attention is called to the desirability of making the cathode in two pieces which can be inserted separately into the tube and held in a socket on the end of the cathode stem. In this way a cathode one hundred and twelve millimetres in diameter can be put into a tube where the opening is not larger than is required for one of fifty-six millimetres.

Electrical Review, November 30, 1901.

NOTE 133 — ON THE THEORY THAT X-LIGHT IS A FLIGHT OF CHARGED PARTICLES OF MATTER

A number of physicists believe X-light is a flight of particles of matter, shot from the target of an X-light tube. A considerable number of experiments have been described in earlier notes which appeared to support the theory advanced that X-light was an ether phenomenon, and now an experiment which seems adverse to the theory that X-light is a flight of particles will be mentioned. A condenser was made of five hundred sheets of aluminum, the X-light being sent through it. The intensity of the transmitted light was measured and the condenser charged. The intensity of the light was measured again and found to be unchanged.

Suppose the light had been a flight of particles of matter charged with negative electricity. When these particles struck the first layer of aluminum, which had a positive charge, they would have been neutralized. If any had passed through the metal they would have encountered a negatively charged second sheet of aluminum. Their velocity would have been reduced and their direction of motion changed from forward to backward. If any escaped this second layer they would have struck next a positively charged surface, meeting the same reception as at the first. These results would in turn have been repeated through the pile. It is not reasonable to suppose by the time the particles had passed through five hundred layers of charged aluminum foil their number would not have been diminished and the light have become less bright. As already stated, it was unchanged. The result would have been the same had the X-light been composed of particles with positive charges. The condenser was revolved to see if there was any deflection of a beam of light passing through it. None was observed. Surely such a deflection should have appeared if the light had been composed of a flight of particles even though these started out with such a high velocity as has been erroneously given to such particles, for long before the stragglers passed through the last of the five hundred sheets they must have been moving slowly.[100] In the

[100] Note added 1903. — The experiment must not be interpreted to mean either that X-light or light viewed as waves in the ether cannot be carried forward by a rapidly revolving disk to which they are transparent. This is a problem on which work has been done during several summers. The results will be printed later. The method used

American Journal of Science for November, 1900,[101] experiments adverse to the idea that X-light is a flight of uncharged particles were given.

Electrical Review, December 28, 1901.

NOTE 134 — ON PHOTOGRAPHIC RESULTS WITH X-LIGHT

In these notes fluoroscopic results have been chiefly considered because they were of prime importance to my friend, Dr. F. H. Williams, as they must always be to the physician as distinguished from the surgeon. Not until apparatus powerful enough to take instantaneous photographs of the soft tissues in the thick parts of the body comes into use can photography prove as valuable to the physician as the cryptoscope. For many cases it will always be of less importance. For the surgeon who wants

— that of interference — is not at present applicable to X-light, therefore the experiment with the aluminum condenser could not have been expected under the conditions to have shown any alteration in the position of the image if this was made by ether waves. This aluminum condenser was used to test the effect on the radiations of pure radium-bromide which act on a barium-platino-cyanide screen. So far as the eye could detect, the illumination of the screen was not diminished when the condenser was charged. A piece of tinfoil one-tenth of a millimetre in thickness was placed in the path of the rays which then struck the screen. The tinfoil was charged positively, but the illumination of the screen appeared unchanged. The same result followed with the tinfoil negative. As the Beta rays are said to have negative charges, it was supposed charging the condenser or the metal foil would diminish the illumination of the screen. The theory of Note 133 may be incorrect, therefore, so far as it relates to the stationary condenser. All the experiments will be repeated. The Alpha radium rays were not allowed to strike the condenser or tinfoil.

[101] Reprinted as Note 109 A.

photographic records, especially in diseases of the bones, where details of structure are of great value, photography is superior to eye observations. No fluoroscopic screen as yet gives the beautiful definition of a photograph obtained by the light of a tube in which the cathode stream particles strike the same spot on the target at uniform velocities in rhythmic surges. It has been shown, in previous notes, that for the present most observers need to practise economy by storing the current in reservoirs connected with the secondary of the induction coil, sending it in powerful surges through the tube to cause each surge to give the right quality of light in the proper amount, the number of surges being reduced to the smallest which will permit the light to be continuous to the eye. In one experiment the coil was arranged as already directed for fluoroscopic work, and a tube with large terminals was used. The coil was furnished with reservoirs in the secondary having large storage capacity to produce surges of proper size. With this arrangement light of the correct quality for the fluoroscope was supplied in surprising volume, but the photographic results were not in proportion to the cost of the coil. Mr. Heinze then used tubes with cathodes as small as those we employed for high-frequency coils, reduced the storage capacity of the secondary to fit the cathode, and sent the surges as fast as possible. A target capable of standing a large amount of heat was employed. Under these conditions it was possible to take a photograph of a hand with a short exposure. There were several reasons why this could be done. Some of these have been mentioned in earlier notes, but will be repeated. First, in Note 6 it was shown X-light contained many different wave-lengths, some so short that, -as pointed out by Elihu Thomson- they do not affect any apparatus. But leaving out of account these shortest waves, there are others which will not affect a photographic plate, yet will brightly illuminate a fluorescent screen. Second, in Note 45 — on harmonics — it was shown to get the best results from the least power, the surges should come in regular order. In the case of a fluorescent screen which makes the X-light visible by reducing its wave-lengths several octaves, the active salts are phosphorescent to a slight extent, the available light in consequence being less dependent upon having the cathode surges regular and rapid. In considering photographic results we may liken the large aggregations of bromide of silver particles to a complex structure like a bridge; the surges to a great number of soldiers. If the soldiers move irregularly, the effect produced on the bridge is slight; but if the movement is rhythmic, there comes a time when the bridge is in danger, and this is what happens with the photographic film, only it is carried further, the bromide groups being affected by the rhythmic surges faster than by irregular ones. — Electrical Review, December 28, 1901.

NOTE 135 — THE SOURCES OF THE CATHODE STREAM

It was said in earlier notes that the cathode stream particles came from several sources, the terminals and the residual gases. The importance of allowing those from the residual gases and from the anode to reach the cathode was shown by means of tubes with movable terminals. Another unpublished experiment bearing on this matter is mentioned here. The cathode of an X-light tube was placed in a glass receptacle with an opening only large enough to allow the stream to pass through it. When the gases from the cathode had been removed by heat and heavy surges, the tube was of no practical use as a source of X-light, for the free circulation of the gases having been prevented, the cathode stream did not recuperate.

Electrical Review, December 28, 1901.

NOTE 135 A — NOTES ON X-LIGHT: RADIABLE WINDOWS IN X-LIGHT MASKS

In treating those surface conditions to which X-light is applicable, it is the custom to use a non-radiable mask with a hole in it to admit the light to the diseased area. As it is not easy to cut the hole to correspond accurately with the irregular outlines of the diseased area, or to adjust the mask to bring the hole into correct relations, another way is mentioned. The hole in the non-radiable mask is made larger than the area to be treated, the opening being covered with thin, transparent celluloid, gelatine or collodion, held in place by rubber or other elastic cement. The mask is then adjusted to the patient, the celluloid being covered with a non-radiable paint applied with a small brush up to the edges of the diseased area. As this diminishes under treatment, fresh paint is applied. Two kinds of paint may be used, one which dries quickly, — white lead in japan or shellac, — another which does not dry, — white lead in petrolatum. The latter is useful, as it can be quickly wiped off and applied again, when at a second sitting the mask has not been put in exactly the same position. The paint is kept in a bottle with a wide mouth, closed by a rubber cork through which passes the handle of the paint-brush. The paint and brush, not being exposed to the air, are always ready for use. If it is considered desirable to protect a patient from the space of strained ether surrounding an excited X-light tube, the paint may be made of finely divided metals of high atomic weights, instead of their oxides or salts, in which case the mask should be grounded.

Boston Medical and Surgical Journal, December 19, 1901.

NOTE 136—ON LOWERING THE INITIAL RESISTANCE OF AN X-LIGHT TUBE

In earlier papers it was stated that the quality of the X-light produced by vacuum tubes did not depend entirely upon the degree of the vacuum, as was supposed, but upon the way the current was sent through the tubes and on the condition of the gases amalgamated with the terminals. This was important because it proved the necessity not only of exhausting the air from the tubes, but also the gases from the terminals to such an extent those remaining did not come out too rapidly while the tube was lighted; for the effect of a rapid liberation was to produce a mist in the tube through which the particles from the cathode must force their way to the target. As a result they did not strike with sufficient force to become efficient radiant centres for X-light, the energy of the current expending itself in heating the target, thereby producing light of ordinary wave-lengths instead of X-light. It was found when the terminals had been properly exhausted, or until use did not quickly produce the result mentioned, the resistance of a new tube prepared for photographing the thick parts of the body was so high there was danger of puncturing by the current in attempting to light the tube. Therefore the importance of some method for temporarily lowering the resistance was evident. The method selected was one invented by Crookes during his work on high vacua. He found when caustic potash was strongly heated until most of the water vapor was driven off, the potash would take up part of the water again. To regulate the vacuum in a tube he placed boiled-out potash in a small bulb connected with the tube, applying the heat from a spirit lamp to liberate the water. His method, though sufficient for experimental purposes, was not convenient or delicate enough for practical work with X-light tubes. A piece of fine platinum wire was therefore placed in the bulb containing the potash, bringing the ends to the outside, where they terminated in loops to which were attached the wires from a source of electricity. When the current was closed the wire became heated, liberating particles which lowered the resistance of the tube. By graduating the temperature of the wire it was possible to keep the requisite number of particles in the tube, to insure the X-light being of any desired quality; from the short waves necessary to penetrate the thick parts of the body without so much diffusion as to obliterate structure, to the longer waves required for showing marked contrasts between tissues differing but little in density.

In another regulator the platinum was in the form of a spiral wound on a tube of mica which slipped over the tube containing the potash. Several simple means were devised to regulate the number of particles in the tube by varying the temperature of the platinum wire. When a constant and abundant source of current, as from a street main, was available, it was only necessary to have a variable resistance in series with the wire, the adjusting handle of the rheostat being placed near the operator's hand, that he might control the heat while making the exposure by X-light. Such a source of current was not found necessary, a few dry cells answering every purpose, only in that case a variable resistance was not desirable, for one could not afford to degrade the limited supply of electricity into heat by a resistance except in the platinum itself. To meet this condition a revolving disk of hard rubber or other insulating material was devised with radiating strips of metal fastened to the side; connection with the electric circuit being made by two bands of metal, one on the axle, the other movable from near the centre to the periphery of the disk. When the movable strip made contact with the radiating arms near the centre of the disk, the current could flow through the fine platinum wire in the regulator during one revolution of the commutator for a longer time than when the movable strip was near the periphery. Several other simple means of accomplishing the result were designed, but they are not given here because this note is not intended to describe mechanical devices, but to call attention to a principle which is still overlooked by most makers of tubes; namely, lowering the initial resistance of an X-light tube and maintaining the vacuum at any desired point by electrically produced heat in a substance -not necessarily potash-, the liberated particles being allowed to pass back into the chemical, by reducing the temperature of the platinum wire, as the particles coming out of the terminals into the tube increase in number through the continued lighting of the tube.

A second reason for this note is as follows: In earlier notes it was said X-light was a result of the high temperature produced in the particles of the cathode stream by their impact on the target, and finding a spectrum like one attributed to hydrogen the opinion was advanced that the initial brilliancy of an X-light tube was due to light sub-atoms in the cathode stream, some of which were hydrogen. Recently Trowbridge has said the spectrum usually attributed to hydrogen is due to water vapor, and that X-light is not caused by the heat of bombardment, but by the dissociation of water vapor at the target. Therefore a description of a simple means for operating a water-vapor regulator should be interesting to those who are studying his theory.

Electrical Review, January 4, 1902.

NOTE 136 A—VACUUM TUBE BURNS

The first report of burning from a vacuum tube was probably by Hawkes, in the Electrical Review for August 12, 1896. He stated the burns were produced by X-rays. Tesla, in the same journal for December 2, 1896, said they were not due to X-rays, but to ozone, and possibly to nitrous acid. In the number for January

5, 1898, it was reported that these burns could be produced by electricity when no X-light was present.[102] In the Boston Medical and Surgical Journal for February 14, 1901,[103] it was stated when guinea pigs were protected from all electrical effects they could be killed by X-light without any "X-ray burns" appearing. In the issue for February 28 it was reported that abortion had been produced by X-light.[104] These results were not accepted. That a motion of the ether, of whose existence none of our senses made us conscious, could kill animals was too new and remarkable a fact to be believed. Physicians said guinea pigs were delicate, therefore the experiments proved nothing; that the precautions taken to exclude the participation of electricity in the results were inadequate; that X-light could not kill a cryptogam, therefore it was not probable it could affect one of the higher animals. Lastly, the pathologist to whom some of the material was given appears to have made no use of his opportunities. Emerson once said what was excellent was permanent. These were excellent experiments, therefore another of them is mentioned. Four strong guinea pigs were used. Two were exposed to X-light under the conditions mentioned in the notes of February 14 and 28, and March 28, 1901, for protecting them from the effects of ultra-violet light, electric induction and convection. The others were subjected to the same treatment and handling except that no X-light was allowed to shine upon them. It was possible to burn the animals before they were killed. Experiments, therefore, have certainly

[102] Note 12. [103] Note 123. [104] Note 124.

proved "X-ray burns" can be produced by X-light when no electricity is present, and by electricity when no X-light is present. The generator used in the experiments was an influence machine with sixteen glass plates, averaging two metres in diameter. The speed was one hundred and twenty revolutions a minute. The tube had an oxygen vacuum. The diameter of the aluminum cathode was fifty-one millimetres. Its mass was fourteen grammes. Its radius of curvature was thirty-five and a half millimetres. The target was of the rotary type. It was made of a disk of platinum-iridium twenty-eight millimetres in diameter and twenty-eight one-hundredths of a millimetre thick. Its distance from the cathode, unless otherwise stated, was seventy-one millimetres. The target was kept red-hot with a white-hot area where the cathode stream struck. The resistance of the tube with the target at seventy-one millimetres was fourteen millimetres. Fresh oxygen was introduced from a regulator, containing manganese dioxide,[105] when the resistance of the tube rose above fourteen millimetres. The double Faraday chamber employed to contain the pigs was made of tinned iron, forty one-hundredths of a millimetre thick. The side of each chamber toward the vacuum tube was made of aluminum twenty-six one-hundredths of a millimetre thick. Air was admitted through iron wire gauze with spaces seventy one-hundredths of a millimetre square between the wires. The gauze was on the side away from the tube. When a pig was being exposed, his nearest side was fourteen centimetres from the radiant

[105] Refer to Note 23.

area of the target. It will be observed before the X-light could shine on a pig it passed through two thicknesses of aluminum, the outer one connected with the earth by a metal wire. It should also be remembered Tesla and others have stated a single thickness of aluminum was a protection against "X-ray burns." These experiments showed burns could be produced and animals could be killed by X-light after it had passed through two aluminum screens. What an aluminum screen is able to do is to protect from ultra-violet light, from the ether strain surrounding an excited tube, from electric convection, and from whatever rays it can absorb. The following table gives details of an experiment. The weights are gross. To find the net weights deduct the weight of the inner chamber, three hundred and fifty-seven grammes. It will be observed Pig 2 showed practically no external signs of burning though abortion and death resulted. This illustrates that animals vary in susceptibility to the external action of X-light and warns us to consider these differences when patients are treated by X-light. What may be a harmless exposure to one patient may cause a burn in another. Pigs 3 and 4 were placed in the same Faraday chamber as Pigs 1 and 2, remaining there for the same length of time. They were therefore exposed as long to ozone and nitrous fumes and handled as much, yet they remained in perfect health. All the pigs lived in the same pen, received the same care and food, the latter in unlimited amount. The whole series of experiments showed we had in X-light, after excluding the participation of all other agents in the results, a force of great

TABLE SHOWING EFFECTS OF X-LIGHT ON GUINEA PIGS

No. 1. Male. Exposed to X-Light in Faraday Chamber.

Day.	Weight in Grammes.	Length of Exposure. M.	Spark-Length of Tube. Mm.	
1	1,078	15	14	
2	1,033	15	14	
3	1,045	15	14	
4	1,047	15	14	Hair losing gloss.
5	1,012	15	14	
6	?	0	..	
7	?	0	..	
8	1,001	15	14	Loss of hair on flank next the tube. Area, 2 sq. cent.
9	?	0	..	
10	?	0	..	
11	991	15	14	Exudation on bare area.
12	990	15	14	
13	971	15	14	Area enlarging.
14	976	15	14	
15	982	15	14	
16	999	15	14	Scabs forming.
17	984	20	14	Improving.
18	975	20	14	
19	981	20	14	
20	?	0	..	
21	994	30	14	
22	971	30	14	
23	986	30	14	
24	964	30	14	
25	976	60	14	
26	959	60	14	Bare area suppurating.
27	?	0	..	
28	980	60	14	
29	954	60	14	
30	945	90	14	
31	936	90	2	Area, 7.5 sq. cent.
32	908	90	2	Partial paralysis of hind leg on burnt side.
33	886	90	2	
34	?	0	..	Died.

No. 2. Female. Exposed to X-Light in Faraday Chamber.

Day.	Weight in Grammes.	Length of Exposure. M.	Spark-Length of Tube. Mm.	
1	746	15	14	
2	740	15	14	
3	755	15	14	
4	755	15	14	
5	751	15	14	
6	?	0	..	
7	?	0	..	
8	758	15	14	Hair losing gloss.
9	?	0	..	
10	?	0	..	
11	747	15	14	
12	772	15	14	
13	750	15	14	
14	757	15	14	
15	752	15	14	
16	769	15	14	
17	762	20	14	
18	762	20	14	
19	763	20	14	
20	?	0	..	
21	781	30	14	
22	765	30	14	
23	779	30	14	
24	778	30	14	
25	781	60	14	
26	771	60	14	
27	?	0	..	
28	777	60	14	
29	746	60	14	
30	726	90	14	Eye closing on side next tube.
31	697	90	2	Slight paralysis of hind leg next tube.
32	667	90	2	Blood from vaginal opening.
33	643	90	2	Aborted.
34	?	0	..	Died. No external or X-ray burns.

No. 3. Male. Not Exposed. Control.				No. 4. Female. Not Exposed. Control.			
Day.	Weight in Grammes.	Length of Time in Faraday Chamber. Min.		Day.	Weight in Grammes.	Length of Time in Faraday Chamber. Min.	
1	931	15		1	756	15	
2	931	15		2	756	15	
3	920	15		3	772	15	
4	926	15		4	771	15	
5	930	15		5	781	15	
6	?	0		6	?	0	
7	?	0		7	?	0	
8	930	15		8	792	15	
9	?	0		9	?	0	
10	?	0		10	?	0	
11	917	15		11	804	15	
12	945	15		12	830	15	
13	930	15		13	823	15	
14	918	15		14	827	15	
15	918	15		15	827	15	
16	926	15		16	852	15	
17	921	20		17	841	20	
18	909	20		18	850	20	
19	915	20		19	860	20	
20	?	0		20	?	0	
21	930	20		21	893	20	
22	925	20		22	886	20	
23	931	20		23	906	20	
24	932	20		24	908	20	
25	926	60		25	923	60	
26	925	60		26	917	60	
27	?	0		27	0	0	
28	939	60		28	941	60	
29	930	60		29	925	60	
30	932	90		30	941	90	
31	949	90		31	956	90	
32	950	90		32	943	90	
33	953	90	Good health, fine coat, bright eyes.	33	956	90	Good health, etc.

When the spark-length was 2 mm., the target was 35 mm. from cathode. The exposures are given in minutes. Length of spark-gap of tube in millimetres.

power, whose action was not understood, whose effects on the tissues were unknown. The attempt to get a pathologist interested failed, and as my knowledge of the normal microscopical appearances of the tissues of guinea pigs is insufficient to make the observations worth publishing, it is hoped some clear-eyed observer will realize here is a new field where useful original work can be done.

Boston Medical and Surgical Journal, January 9, 1902.

NOTE 136 B — RADIO-ACTIVE SUBSTANCES IN THERAPEUTICS

During the year 1900 experiments with radio-active substances were made, hoping to find a substitute for X-light. Some of the radiations retained their activity after passing through animal tissues as thick as the body of a guinea pig. Being convinced of the value of radium, about five hundred milligrammes of an activity of one thousand were placed in a sealed capsule to protect it from moisture, and given to Dr. Williams with the request that it should be tried on lupus, a disease which at that time was interesting to him. The capsule was disk-shaped, with a front of aluminum, a back of comparatively non-radiable metal. It is believed to be important to test these substances in the treatment of lupus, superficial cancer and diseases of the skin in which X-light has been found useful; therefore, another capsule will be sent to any Boston physician who will give the matter a fair trial.[106] Radio-active substances can be used in sealed capsules held against the body by adhesive plaster, or they can be made to cover larger areas by mixing

[106] Note added 1904. — Considering the present interest in radium, it may be worth while to say that no application was received for this capsule.

them with rubber or celluloid to form moisture-proof plasters. These plasters may be still further protected by being coated on the sides nearest the body by aluminum foil and on the opposite sides by lead foil. They could be kept in stock by the yard by druggists and given to patients by prescription, with proper directions as to the length of application. They could be worn at night. Their use would prevent the poor from making such frequent visits to a physician as are now required when X-light obtained from a vacuum tube is used. This is a matter of some importance, as the present treatment takes many sittings, which require time and cost money.

Boston Medical and Surgical Journal, January 23, 1902.

NOTE 136 C—RESISTANCE IN HIGH VACUA

The statement is frequently made that the resistance to the electric discharge in high vacua follows an inverse rule from that governing discharges at ordinary pressures. In air at atmospheric pressure the resistance increases for moderate distances as the length between the terminals increases, while in high vacua the resistance is said to diminish as the distance between the terminals increases. If the latter were true it would be so discordant with known laws that during several years experiments have been made with freshly prepared X-light tubes to see what could be learned. The conclusion was reached that the accepted opinion was not correct. When the resistance in high vacua appears to follow another rule from that governing in air, it is because the true condition is masked. To show the same law applies in both cases, results obtained from tubes recently prepared for experiments on burning the skin are mentioned. These had the movable terminals described and figured in the Electrical Review for December, 1897, and January, 1898. They were carefully prepared with heat and heavy surges during pumping to get the terminals in proper condition for the current afterward to be used in exciting them. In Number One, the target -anode- was placed forty millimetres from the cathode. In this position the resistance to an amount of current suitable for the tube was equal to four millimetres of air at atmospheric pressure. When the distance between the cathode and target was increased to one hundred millimetres, the resistance increased to ten millimetres of air. In Number Two, under the same conditions, the resistance was equal to eight millimetres and twenty millimetres of air. In studying the resistance of high vacua, X-light tubes are valuable, as they are very sensitive, and it is important to consider the conditions which determine the production of a regular cathode stream, — such as the form of the terminals, the condition of the gas amalgamated with them, the establishment of a normal circulation of the residual gases -depending on the form of the tube and the relations of the terminals to it-, the amount of the current and the size of the surges which are sent through the tube.

American Journal of Science, January, 1902.

NOTE 137 — AN INDUCTION COIL FOR X-LIGHT TUBES AND WIRELESS TELEGRAPHY

Several years ago I designed an induction coil of value to experimenters because it could be easily, quickly and cheaply repaired. When the modern forms of electrolytic or Spottiswoode breaks came into use, it was found induction coils in general frequently broke down under the strain of the strong currents which these breaks made it practical to use. Therefore a short description of the coil was given in this journal for December 26, 1900.[107] This coil differed in several ways from those in use. Instead of the usual hard rubber tube between the primary and secondary, one built up of many sheets of mica was used. These tubes, which can be obtained from the Micanite Company now in any size, are essential in induction coils which are expected to bear strong currents. The design of the secondary was new. The most practical induction coils commercially available have been made for years on the plan first proposed by Poggendorf before 1850. One of his coils, made by Siemens & Halske, was shown at the exhibition in London in 1851. Poggendorf's [108] method consisted in winding the secondary in thin sections. In the coil mentioned the sections were wound on a long grooved hard rubber cylinder. More recently makers have used paper; in consequence the coils have been less durable. All these sections have been fastened together into a solid mass by means of insulating substances, like paraffine or wax. The defects of this method are well shown in the following quotation from a recent work, Induction Coil and Coil-Making, by Allsop, in which Mr. Ward, who made for Mr.

[107] Note 112.

[108] In Note 112 this method was erroneously attributed to Ritchie.

Apps the Polytechnic and Spottiswoode coils, speaks of repairs on the former. He says, "But owing to the parsimony of the directors of the Polytechnic they did not avail themselves of these two most necessary elements of success. They elected to move it themselves, and, owing to an enormous undue strain being put upon the primary tube in so doing, it was either cracked incipiently or so weakened that when they separated the terminals to a certain distance, through went a spark. This time the damage was repaired by Mr. Apps, which I am sure everybody who knows anything of the almost insurmountable difficulties of withdrawing the old tube and putting in a new one without damaging the ponderous and delicate secondary will admit was a triumph of mechanical skill."

When we combine this difficulty with the greater one of repairing the secondary, it is very evident such a construction is not well suited for coils that are to stand the strain of powerful currents. That the secondary needs some better method of construction is also shown by the fact that the second of the coils mentioned, the most famous coil yet constructed, now gives a spark much less than the original length. Moreover, this proves the methods in use for insulating the secondary, notwithstanding the great mass of insulating material employed, are not durable. They are also inconvenient, for a coil should be so constructed repairs can be made in a few minutes by unskilled persons, without returning the coil to the makers. Therefore the sections of the secondary were made entirely independent of each other, and perfectly free from the tube separating them from the primary. It was thus a simple matter to remove any injured section by drawing out the micanite tube enough to free the section. No insulation was used about the coils, except the glass plates,[109] to which they were attached in pairs, one plate and two coils forming a section. The sections were separated from each other by glass plates having holes in their centres only large enough to allow the micanite tube to pass through them. The holes in the glass plates to which the coils were tied were somewhat larger, to prevent a spark from jumping from one section to another over the intervening glass plate. After this coil was described, the method of construction was said to be without value, because the insulation was so imperfect the coil would soon break down. No one believed such a simple method of insulation could be efficient. Since that time two other coils have been made, one of fifty-six, the other of seventy centimetres' spark-length, in which the same method of insulating the secondary was used. These coils have proved durable. If coils could be built without money, one would be constructed on this plan to give a spark several metres long. Probably the last of the prophets died long ago, but as it is possible some who have criticised the insulation of this coil may belong to that class, designs are given for two other methods of insulation which yet preserve the important features of complete independence of the sections of the secondary from each other and from the primary tube. First, however, are shown a few figures of the original construction

[109] Micanite plates were recommended in Note 112. They are stronger and thinner than glass.

for a fifty-six-centimetre coil, a convenient size for all electro-therapeutic work that has been done by static machines. For X-light a larger coil should be used. Plate 60, Figure 1, illustrates one of the sections, consisting of two coils of double cotton-covered wire thirteen one-hundredths of a millimetre in diameter attached on each side of a micanite plate twenty-eight centimetres in diameter. In the centre of the plate is a hole to allow the section to be strung on the micanite tube separating the primary from the secondary. The weight of copper wire in each coil is one hundred and forty grammes, this weight including the cotton covering. Each coil is four millimetres thick. The coils are attached to the plate by tape soaked in paraffine. Plate 60, Figure 2, is a sectional view of the coil, showing the connections of the sections. The micanite tube was one hundred and twelve millimetres long, with a bore of seven centimetres and walls two centimetres thick. The coils could have had a smaller diameter, but it was considered best to make them of such size that they could be used for a larger coil. The number of the coils was seventy-six. Plates 61 and 62, Figures 3 and 4, show another method of insulating the sections. This was never carried out except in an experimental way, because the glass cells could not be obtained. An experimenter can obtain no satisfaction from the glass manufacturers, because he cannot give orders for a thousand things all alike. The figures are published because the method is practical and simple. Directions will now be given which will enable any one who has a reasonable amount of mechanical skill to construct a seventy-centimetre induction coil suitable for the powerful currents needed in wireless telegraphy and in X-light work.

THE PRIMARY

This consists of a central rod of soft iron two hundred and twenty centimetres long, one centimetre in diameter. It is provided with two cup-shaped flanges. One is fastened near one end by two lock nuts. The other can be clamped by a set screw in any position on the rod. The object of the flanges is to keep the rod central and to hold the ends of the surrounding wires in place. These wires are of the softest iron, each one hundred and sixty-eight centimetres long and one millimetre in diameter. They form a mass surrounding the rod. Outside the wires is a single layer of insulated copper wire whose diameter is four and eighteen one-hundredths millimetres.

METHOD OF CONSTRUCTION

A metal tube one hundred and sixty-eight centimetres long and eighty-nine millimetres in internal diameter is used for packing the wires, as shown in Plate 63, Figure 5. One of the cup-shaped flanges already mentioned serves to close one end of the tube to which it is temporarily fastened by a collar and set screws. To keep the other end of the rod central during the packing, an open flange with a central boss holding the rod is attached temporarily to the other end of the tube. When the wire is all firmly packed in the tube about the rod, it is necessary to push it out a little to begin the process of tying. As it is essential all the wires be pushed out evenly, a plunger exactly fitting the tube is used. Its handle is hollow to allow it to slide over the central rod. This is shown in Plate 64, Figure 6. Plate 65, Figure 7, illustrates the method of tying with strong cord. When one band of cord is attached, the wires are pushed out a little more to allow another band to be tied on, these operations being repeated until the whole core is out of the tube. The second cup-shaped flange is then put on and clamped against the ends of the wires, which are thus securely held between the flanges. The whole mass is soaked in melted yellow ozokerite until no more bubbles come to the surface. After draining, the core is wrapped in strong manila paper, put on diagonally in strips fourteen centimetres wide, the paper being coated at the time with shellac in alcohol. As soon as one layer is dry, another is put on, breaking joints. There should be seven of these layers. Except for the expense, it is better to pack the wire in a micanite tube, thus saving the time used in tying and wrapping. After the paper is dry a single layer of insulated copper wire is wound in a tight spiral around it. Having no lathe long enough to mount the core, it was placed on the horse, one end of which is shown in Plates 64 and 65, Figures 6 and 7. In this position one man can turn the core while the other is winding on the copper wire. When the copper wire is all on, it is heavily coated with shellac in alcohol. After drying, the whole primary is thickly covered with paraffine to make it slide easily in the micanite tube and further to insulate the spirals of copper wire.

TUBE SEPARATING PRIMARY FROM SECONDARY

This tube is of micanite. No other material is suitable. The length of the tube is two metres. Its walls are fifteen millimetres thick. The diameter of the hole is one hundred and five millimetres. The tube is shown in Plate 75, Figure 8.

SECONDARY

This contains one hundred and twenty-six coils of double-covered cotton wire, whose diameter is twelve one-hundredths of a millimetre. Each coil is wound from a single piece of wire, whose weight, including the cotton covering, is one hundred and fifty-four grammes. It is customary to have as many splices in the wire of a single section as happen to be in the wire when it comes from the maker, but as these splices are a cause of the coil breaking down under strong currents, it is better to insist on having the wire in each section in a single piece. The internal diameter of each coil is sixteen centimetres. The thickness of each coil is four millimetres.

METHOD OF CONSTRUCTING THE SECONDARY

It is customary to wind the coils of the secondary by hand. Allsop, in the work already mentioned, shows a section-winder operated in this way, and states it is unnecessary, even if it were possible, to wind the wire in even layers; it must be allowed to find its own level. However, liking to see mechanical operations done in a workmanlike manner, a simple, automatic winding machine is illustrated and recommended, which, winding the wire in even layers, puts more wire into the same space of strained ether, making the coil more efficient. This is a matter of importance, as theory indicates and the experiments show. The machine -Plate 66, Figure 9-, was, as far as possible, made from forgings and such gears and parts as were commercially available, for in this way the cost of many patterns was saved. By means of a tilting carriage, bearing the eye through which the wire is fed to the machine, a to-and-fro motion is imparted to the wire. This motion is communicated to the carriage from a shaft with right and left threads, which come in contact alternately with similar threads on the ends of the carriage. The carriage is tilted automatically. The whole mechanism is so simple that it can be readily understood from the half-tone illustration.

WINDING

The coils are wound on sheet metal forms -Plate 67, Figure 10- sixteen centimetres in diameter, with rims four millimetres wide.[110] The width of a rim determines the thickness of a coil. There are a number of slots in the edge of the winding form to allow the thread to be inserted for tying the coil. One of the forms is placed in the winding machine, between the two flanges of cast-iron with radiating slots, when it is desired to begin the winding of a coil. To insure proper tension on the wire to wind it tightly, it is held in the hand as it is fed to the machine -Plate 68, Figure 11-. When enough wire -one hundred and fifty-four grammes- is wound on, it is tied with linen shoe twine, Number Ten -Plate 69, Figure 12-. Plate

[110] Wheels of metal, with solid rims supported by radial arms, were found superior.

70, Figure 13, shows one flange of the winding machine taken off, the shaft having been first removed from the machine. The figure also shows the disk on which the coil is wound, and a fresh-wound coil ready to be removed. See also Plate 67, Figure 14. The coils are removed from the winding machine on the winding forms to insure keeping their figures until they have been dipped in the insulating and stiffening mixture, after which they are rigid. When enough coils have been wound they are placed on a long-threaded arbor, each separated from the next by a disk of polished tinned iron.[111] Both winding forms and separating disks are perforated with a number of holes to allow the insulating compound free access. When enough coils are on the arbor they are firmly clamped between cast-iron disks turned true on their faces. Considerable pressure should be used to bring the coils firmly together. They are next dipped in a mixture of yellow ozokerite, three parts, and Carolina white resin, one part.[112] The mixture is melted in a water bath, made of galvanized sheet-iron. It is important to use a water bath, for if the flame comes in contact with the trough containing the mixture, this is sure to become carbonized after a time, and these fine particles of carbon get imbedded in the coils. As they are conductors they injure the

[111] Two disks should be used between the coils; because, if the coils adhere to the tin disks after dipping, a chisel can be inserted between the tin disks to pry them apart, leaving one disk attached to each side of each coil. These can readily be removed by placing them on a warm surface. The coils are then left with smooth surfaces, and all risk of displacing the wire is avoided.

[112] Omit the resin.

insulation. The coils are to be kept in the insulating mixture at a temperature of two hundred degrees Fahrenheit for twelve hours to insure the removal of air and its replacement by the ozokerite. The process of dipping the coil is shown in Plate 71, Figure 15. Only one group or one-third of the whole number is seen. In removing the coils from the bath they should be thoroughly drained in an upright position, the mixture flowing out through the holes in the winding forms and separating disks. Afterward they are replaced in the position shown in the picture and kept there until they are perfectly cold. Then the flanges are lifted off, the coils being cleaved from the separating disks and removed from the winding forms. They are then ready for mounting. Plate 70, Figure 16, shows the coils partly removed, and some coils with the winding forms taken out. A few of the coils are placed in an upright position to illustrate their rigidity. They are strong after dipping, as the insulating mixture is tough.

MOUNTING THE COILS ON GLASS PLATES

The mounting may be done with tape or by rings of ozokerite -Plate 72, Figure 17-, or by casting the ozokerite around them -Plate 73, Figure 18-.

BY RINGS OF OZOKERITE

Second Method — Plate 72, Figure 17, shows the elements of one section of the secondary, three glass plates, two coils and four rings of ozokerite. These are placed together, in the order shown in the figure, and pressed while slightly warm in an oven, forming a section, as seen in Plate 74, Figure 19.

INSULATION BY CASTING

Third Method — The coils and glass plates are fastened together about their edges; they are then warmed and the insulating mixture poured in through the funnel; the arrangement is shown in Plate 73, Figure 18. The ozokerite enters at the bottom to allow the displaced air to escape. When the mixture is cold, the funnel is removed and the gate trimmed smooth. The coil then looks as in Plate 74, Figure 19, referred to in the second method. Under all conditions of our Boston climate the last two methods are unnecessary, but they are given because the coil thus made is especially valuable for wireless telegraphy, which is expected to find a large field on shipboard and in other damp positions, though under any atmospheric conditions of the temperate zone the first method is satisfactory. The last two methods are valuable where the coil is to be made as portable as possible and to be exposed to the risks of transportation, for the insulating mixture makes the sections capable of bearing quite rough usage.[113]

CONNECTING THE COILS IN EACH SECTION

This operation comes before insulating, but for convenience it is described later. The most difficult part of a coil to understand is the connections of the two coils forming a section. The best plan is to consider them as one coil split by accident. If they are placed to represent one coil, the inner ends of the wires being joined by twisting, they are in the proper relation to each other; that is, they form a continu-

[113] A simpler way is to cast each section in a suitable flat tray.

ous coil of wire in which the turns all go in the same direction. Once there was a coil which did not work well, because in one or more sections the turns of wire in the two half-coils went in opposite directions. This is a mistake easily made.

PACKING THE SECTIONS IN BOXES

An inspection of Plate 75, Figure 20, will show that the coil, instead of being in one piece as usual, is packed in three independent boxes. For a coil of this size this is an important feature, for the great weight of the coil makes it sometimes inconvenient to handle in one piece.[114] The Leyden jars and the spark-gaps are attached to separate end-pieces, which can be used at the ends of a single section if a small coil is wanted, or as shown in the figure, when a large one is required; but even with them, as illustrated, the coil may be used as a small coil by a provision to be mentioned later. All the boxes and the end-pieces slide loosely on the micanite tube, and can be easily removed for transportation. This is shown in Plate 75, Figure 21. The centre of the top of each box is made of a strip of plate-glass, which has holes for the insertion of brass balls, to which certain of the sections are attached. This arrangement has been fully described in Note 112. The plan enables the coil to be used either as a seven or a seventy centimetre coil, or one of any size between, by moving the potential rods to the appropriate balls in the glass plates.[115] Before

[114] In a more recent coil only two were used.

[115] If the maximum spark from a small amount of energy is desired, this feature is not recommended.

connecting the sections together they are placed in the wooden boxes, the slack being taken up by a rubber pad.

CONNECTING THE SECTIONS

Begin at an end section. The outside wire is connected with an end ball in the glass plate. The second wire coming from outside of a section is connected with the nearest outside wire of the next section, and so on through the box, except when a section comes under a brass ball one of its outside wires is attached to the ball, as is the first outside wire of the next section. This is shown in Plate 60, Figure 2.

CONNECTING THE BOXES

After the boxes are placed side by side on the micanite tube, the nearest balls are connected by metal loops to make a continuous wire through the whole secondary.

REMARKS

It will be observed that the coil has much less wire in the secondary than the coils of which descriptions have been published. For example, the Polytechnic coil, already referred to, which in its best estate gave a spark no longer than this one, had about two hundred and seventy-five kilogrammes of copper wire in the secondary, while in this coil there are but thirteen kilogrammes of copper, for the wire, including the cotton covering, weighs but nineteen kilogrammes. The exact weight of the copper may vary slightly from the figures, though these were obtained from the makers of the wire. It will be seen the weight of the copper in the secondary is only a twentieth of that in the Polytechnic. As the wire costs over four dollars a kilogramme, this is an important matter. There are several reasons why so small an amount of wire is required. First, the modern forms of the Spottiswoode or electrolytic breaks are more efficient than the breaks formerly used. Second, the secondaries of the coil have been unwisely placed in regard to the space of strained ether produced by the primary, therefore many turns of wire have been necessary to get the required spark-length. In this coil the secondary is immersed in more strongly strained ether by making the primary of what will be considered an excessive length and constructing the secondary in such a manner very strong currents can be induced in it without risk of breaking it down. Now the street current is available for exciting the primary of a coil, our source of power is practically unlimited, therefore coils can be made much simpler, provided they are made strong enough. There is no condenser, because the coil is intended for electrolytic breaks.[116] The electrolytic break should be of a type which works regularly, and in which the volume of current can be regulated by a conveniently placed handle which may be manipulated while the coil is in action. To avoid repetition several matters relating to the coil

[116] A condenser and ordinary interrupter may be used, in which case the spark will be shorter; or the primary may have an alternating or pulsating current sent through it without any interrupter, in which case the length of spark will depend upon the rapidity of the rate of change. With special dynamos the spark-length is considerable from small coils. This is a convenient way of exciting an inductorium.

have been omitted, as they were mentioned in Note 112, which should be read in connection with the present note. When a coil, of the power of this one, is used to excite an X-light tube with a strong current in the primary, the tube needs to be proportioned to the current, therefore in a future note directions will be given for designing and constructing such a tube.

Electrical Review, March 29, 1902.

NOTE 138 — TUBES FOR POWERFUL COILS

It has been frequently said powerful apparatus of the type shown in Notes 112 and 137 was unsatisfactory for exciting X-light tubes, because, though it gave brilliant pictures on a fluorescent screen, the photographic results were not so good as those obtained from less powerful coils and from small static machines. To one who has always advocated more powerful generators for exciting X-light tubes, this was disappointing. Some experiments were therefore made to determine why powerful apparatus did not give better results in the hands of the critics. These experiments showed the fault was not in generators, but in the tubes commercially available, which would not bear strong discharges without the vacuums falling until the light was not of the proper quality for photographic work, though by means of powerful surges, which imparted a higher velocity to the sub-atoms in the cathode stream, the fluorescent screen could be strongly lighted. Until instantaneous photographs of moving organs, like the heart and lungs, can be made without a fluorescent screen, experimenters who believe in more powerful apparatus and are trying to have it adopted should be encouraged. No one expects to get as much light from the current used in a sixteen-candle-power Edison incandescent lamp as from that used in a fifty-candle-power lamp of the same type. It is as absurd to claim as much X-light can be obtained from a small coil or static machine as from a coil capable of yielding many times as much current, for X-light can no more be evolved out of nothing than ordinary light of longer waves. We should learn to make tubes which will bear powerful currents and efficiently convert them into X-light. In former notes principles were stated which enable this to be done. In the present note a tube constructed on these principles, which is suited to the seventy-centimetre coil described in the last note, will be described and figured. Directions for pumping will also be repeated, as this is a matter of importance not generally understood.

The tube is shown in Plate 76, Figures 1 and 2. It is five hundred and sixty millimetres long. The bulb is one hundred and twenty-six millimetres in diameter. The target is placed at the actual instead of the theoretical focus of the cathode to insure sharp definition -Note 1, December 1, 1897-. As this focus varies with the charge on sub-atoms in the cathode stream -Note 86, February 7, 1900-, and on the degree of the vacuum -Notes 2 and 3, December 8 and 15, 1897; Note 6, December 22, 1897-, it is important to have the target or the cathode movable -Note 4, December 15, 1897; Note 19, January 26, 1898-. There are advantages in having the cathode movable, as in this case the adjustment can be made magnetically -Note 19- during an exposure. As the X-light arises from the target, if this is not moved, the radiant area is stationary, therefore the definition is good. Usually it is better to move the target, however, not attempting to make any adjustment during the exposure of the photographic plate, depending on a vacuum regulator of the type invented by Crookes, which liberates water vapor on heating, reabsorbing it again on cooling. In this way the focus of the cathode stream is kept nearly at any predetermined distance from the cathode, according to the kind of light required -Note 6, December 22, 1897, Note 10, January 5, 1898-. As a mechanical control of the position of the terminals is simpler, though not more convenient than a magnetic one, the former is shown in Plate 76, Figures 1 and 2. The end of the stem of the target nearest the iridium or iridium-platinum disk is square, with shallow parallel notches on two sides, the others being smooth. The object of the notches is to allow the target to slide loosely in the steel tube supporting it, yet to prevent it from being moved from its place during an exposure by the attraction existing between the terminals -Note 66, October 25, 1899-. How strong this attraction may be was well shown in some targets with smooth stems. In one experiment the anode, to approach the cathode, was obliged to climb a grade of two degrees. This it would do in an hour, frequently in less time, finally coming in contact with the cathode. When the terminals almost touched, there was a bright spot whose effect upon the cathode was interesting and will be described in a future note. The end of the steel tube in which the stem of the target slides is covered with a thin steel cap having a square hole in which the square part of the stem fits loosely, the edges of the hole catching in the grooves in the stem of the target, which is thus held very lightly, but with sufficient security to prevent its moving during the time a photograph is being made with the tube. If at any time it is desired to change the distance of the target from the cathode, this may be done by slightly shaking the tube while it is held nearly upright with the cathode end down. The object of having the stem square is to enable the target to be faced in several directions relatively to the vacuum regulator.[117] If there is no vacuum regulator this construction is not necessary, though still convenient, as a round stem, sliding easily in a tube, is likely to be moved out of place by the vibration imparted to the target by the impact of the cathode stream. In some earlier tubes this was overcome by bending the end of the stem, bringing it out through a groove in the side of the tube surrounding it, but this construction is inferior to the one shown here. When it is desired to change the direction in which the target faces, the tube is held in the hand with the target end up. The target then slides out of its sheath toward the cathode until the square part of the stem is free from the sheath. The target can then be turned in the required direction, the stem afterward being allowed to slide back into the sheath to the required distance from the cathode by tipping the tube until the cathode end is higher.

[117] In tubes without adjustable targets the regulator stems should be at an angle to prevent the spark-gap regulator from cutting off part of the beam of X-light escaping through the opening in the diaphragm plate.

PROPER DISTANCE OF THE TARGET FROM THE CATHODE

For most work the best distance of the target is that recommended in Note 1: twice the theoretical focus of the concave cathode, or twice the length of its radius of curvature. In the tube shown here, this distance is eighty-six millimetres. The amount of adjustment of the target on each side of this mean point should be, in a tube of the size under consideration, twenty-eight millimetres.

FORM OF THE TARGET

The target may be of the rotary type mentioned in Note 11, January 5, 1898, and figured in Note 50, February 15, 1899. In addition to the mechanism shown in the latter note it has an automatic clamp which locks it, with the surface below any of the numbered spots, in position to receive the impact of the cathode stream. When it is desired to bring a fresh surface of the target in position, it is only necessary to tilt the tube enough to free the catch, when by a slight turn of the wrist, easily acquired, the desired movement can be produced. By making one arm of the catch heavier than the other, the locking mechanism is effective whether the target faces up or down.

CATHODE

The cathode and its stem are made of aluminum, as recommended by the early workers with vacuum tubes. No metal is better which is not at present too expensive for practical work. The diameter of the cathode is fifty-six millimetres. The thickness and distribution of the metal are well shown in the illustration. It is desirable to have the face of the cathode smooth, therefore the stem should not be riveted on, as is still the custom; the cathode should either be turned and polished in a lathe to the proper curvature, or it should be drop-forged with a projection on the back for attaching it to its stem, as shown in Plate 76, Figure 1. Both these methods have been used. As no difference could be detected in the results, drop-forging is the better, because it is cheaper, if a number of cathodes are required.

POSITION OF THE CATHODE

It was shown in Note 18, January 26, 1898, how much the efficiency of a tube depended upon the position of the cathode relatively to the glass walls, and in subsequent notes a number of well-designed tubes were figured. An experience much longer than was possible at that time has confirmed the statements made, one of which was the cathode should be placed to allow it to gather up the particles in their rushing sweep toward that end of the tube. Further experience has proved the idea of putting the cathode in an annex, Plate 11, Figure 30, Note 30, August 3, 1898, to enable its concave surface to continue the curve of the tube, to aid in the gathering-up process, though afterward adopted by nearly every maker after the tubes of this kind were produced commercially by Frei, in 1896, is of no practical account when powerful generators are used. It should be abandoned, for it increases the risk of puncture, besides making the tube more difficult to blow when large cathodes are used. The arrangement shown in the illustration, where the bulb is symmetrical, makes a tube more graceful, stronger and easier to construct.

STEMS OF THE TERMINALS

The stems of the terminals should not be wrapped in glass, — even at this late date the common method. They should be bare, because with powerful currents the glass gets broken altering the vacuum. Advantage of this fact was taken in some of the experiments to find a good vacuum regulator, a piece of glass being arranged to be heated when it was desired to lower the vacuum. Another disadvantage of using glass wrappings to support the terminals is that the latter get out of line when the glass breaks, to such an extent the tubes often become useless from the jar of transportation or rough handling. The stem of the terminals should be made of bare metal of a diameter not less than five millimetres if made of aluminum, for if smaller they are likely to be bent, as the metal gets very soft in course of preparing the terminals. The tendency is to make tubes much too light and frail.

TERMINAL WIRES

The terminal wires should not be less than eighty-six one-hundredths of a millimetre in diameter. They should not have the form of loops, as a sudden pull on the wires connecting the tube with the coil will frequently result in breaking the ends of the tube. The wires should project about three millimetres, the connection with the generator being made by small spiral steel springs of piano wire attached to the ends of the cables leading from the coil.[118] In this construction the wire is at once freed before a pull of sufficient force to break the tube is exerted. After the terminals are constructed, it is of importance to put them in an oven, heating them to a temperature of seven hundred degrees Fahrenheit, for an hour, to burn the organic matter and lubricating mineral oils which have collected on them from the mechanical operations through which they have passed. How important this is has been shown by experience gained in trying to get tubes made for powerful generators. The tube-makers would neglect this precaution, the necessity of which had often been pointed out to them; consequently in the operation of pumping, the gas would arise from these sources to such an extent by the time it had been removed the proper gases required to produce brilliant X-light had also been so thoroughly removed by the action of the current, the tube was dull. This is one of the most frequent causes of poor tubes. Pumps for exhausting X-light tubes should have connected with them an oven made of iron covered with a non-conducting material, outside of which there should be a sheathing of some material like lead or white lead in japan, opaque to X-light, for it is an injury to a workman to be near powerfully excited tubes day after day.[119] The power of X-light for harm was proved in some experiments on

[118] A better plan is shown in Note 157, Plate 115, Figures 1 and 2.

[119] For illustrations of oven refer to Note 173.

animals which were reported in part in the Boston Medical and Surgical Journal for February 14, 28; March 28, 1901, and January 9, 1902. The experiments showed X-light could burn, kill the fœtus and cause death in adult animals. The oven should have a thermometer which can be read from the outside; a window of lead glass an inch thick to allow the tube to be seen; another window of aluminum through which to observe the quality of the X-light with the fluoroscope. This aluminum window should have a swinging shutter of non-radiable material, to cut off the X-light when it is closed, as it should always be except when at intervals it is necessary to test the light, because the experiments mentioned showed that aluminum, even when grounded, as recommended by Tesla, was powerless to prevent burning, abortion and death, as these results were produced through two sheets of aluminum, one of which was grounded. These experiments were of importance, because they were the first in which all other agents besides X-light were excluded as factors in the results. They clearly showed the precaution which a few careful operators have used, and which was recommended by Tesla to prevent burns, was not efficient. They also proved all kinds of X-light, whether from high or low resistance tubes, would produce not only burns, but death in animals. They therefore showed "the great importance of always using an X-light tube in a non-radiable box from which no X-light can escape except the smallest cone of rays which will cover the area to be examined, treated or photographed." This matter of enclosing a tube has been frequently mentioned in these notes, and a number of such tube boxes have been figured, but as its importance is not yet recognized, it will be again considered in a future note.[120] The oven in which the tube is placed for pumping should be so far removed from the pump the heat shall not affect the mercury or drive off water vapor. This may be easily done by making the tube connecting the X-light tube with the pump about fifty-six centimetres long. Having such an oven, the tube is to be placed in it and heated to a temperature of five hundred and sixty degrees Fahrenheit to burn out the organic matter deposited on the walls from the workman's breath and on the terminals from his hands; to drive out gas from the glass, from the regulator chemicals or the stuff used to hold them from entering the main tube. Glass wool is the best material for this purpose, as asbestos gives off gas. Neglect to follow this advice has caused much trouble in pumping tubes. The heat also drives off the gas from the surfaces of the terminals and prevents mercury vapor from condensing in the tube. No current should be sent through the terminals until this stage is passed. Before the current is used we must be sure gas is not entering the tube from other sources such as leaks in the tube, in the fork, in the joints, from the grease used to make the joints tight or from the water vapor or mercury of the pump, if a mercury pump is used. During the whole process of heating, the pump should be kept in action until the bubbles of the gas stop appearing in the out-

[120] Refer to Notes 143, 149, 155, 156, for useful tube boxes.

let valve. Then begins the second stage of preparing the tube, to which the name "tuning" has been given.[121] It has in earlier notes been shown "that we depend upon gases amalgamated with the terminals to produce an efficient cathode stream for making X-light," "that the process of pumping a tube consists not only in removing the right amount of gas from the tube, but in driving out the proper amount of gas from the terminals, that what remains will not come out so fast, when the tube is used, as to lower the resistance until the X-light is not of suitable wave-length."

When the first stage, or that of heating and pumping without current, is complete, the tube may be cooled to the temperature of the room. Next, connect it with a source of current of the same volume and delivered in surges of the same kind and size and at the same intervals which will be afterward used in practical work. The reasons for this are plain: First, if less current is used during the subsequent pumping than will be employed in practical work afterward, it will be found, when the tube is sealed off and used, that the stronger current will drive gas into the tube until the vacuum is so low the tube is useless, for the wave-length of the light will be too long to be suitable for the work in hand, or the vacuum may be so low ordinary light alone will come from the tube, because the sub-atoms -American Journal of Science, page 391, 1900- of the cathode stream will meet with such obstruction on their way to the target they will strike with too little velocity to be raised to the proper temperature to produce the short

[121] Refer to axioms in Note 177.

ether movements we call X-light. A few experiments will show why not only the amount of the current passed in a given time must be considered, but also the size of the surges. It is only necessary to increase the size of the surges, diminishing their number -to keep the amount passing in a given time the same-, to see how much gas the larger surges will drive out. A tube which has been tuned with small though frequent surges until the vacuum remains in proper condition under such surges may be spoiled by a few more powerful ones. This is what generally has happened when tubes have been tried on powerful generators. It is the chief reason why such apparatus has been condemned, not only by tube-makers, but by physicians who have attempted to work with it. On this account in Note 29 the statement was made that a tube should always be pumped with regard to the generator on which it was afterward to be used. The facts also point out how important it is for every coil to have some means of measuring the energy it is delivering to the tube. Having arranged the current in the proper manner, the pumping is to be continued until the resistance of the tube does not fall too low in a reasonable time while the current is on. Then if there is no vacuum regulator, the tube may be sealed off, as it is finished. If there is a vacuum regulator, this should be heated either by a lamp, a flame or by electricity, if the regulator is of the type shown in the figure, until the light yielded by the tube is of the longest waves which will be required in practical work. The regulator should then cool. If the resistance rises to the former point, all is well. The tube may be sealed and marked to show how much current should be used with it. If the resistance does not rise to the proper point, there is too much gas in the regulator. The heat on the regulator must be continued with the pump in action until by trial with the current the vacuum is found to remain at the desired point when the regulator cools. Then the tube can be sealed and marked. If there is no vacuum regulator that liberates gas, which it reabsorbs on cooling, but one only used to lower the vacuum permanently [122]-when through use this has become too high-, the second operation of tuning up the tube can be carried on at a temperature of three hundred degrees Fahrenheit. In this case the tube should be cooled before it is removed from the pump, to test its resistance, which should be equal to three centimetres of air between polished brass balls two centimetres in diameter. If the regulator is of the first type, the resistance may be left at twenty-eight centimetres for powerful coils.

PUMPS [123]

Either a mercury or a mechanical pump may be used in exhausting tubes, for the process of removing air from a tube is a simple one which may be done in a few minutes. The tuning is where the time needs to be spent. Ignorance of this has caused experimenters to go on complicating the mercury pump with the idea of increasing its efficiency until some of the modern

[122] Refer to Note 175, Plate 136, Figure 2, for a useful vacuum regenerator.

[123] Refer to Notes 170 and 173 for illustrations of mercury pumps.

forms are forests of glass tubes branching in every direction. The best work on mercury pumps is S. P. Thompson's little-known pamphlet. Fortunately, owing to the date of publication, some of the most complicated pumps are not described. One of the features on which investigators have spent most time is in multiplying the number and complexity of the drying tubes. A mercury pump should be simple, with as few joints and tubes as possible. One drying bulb of a globular shape, kept filled with fresh phosphoric anhydride -the word fresh should be written in large letters-, is enough. The best mercury pump is Mr. W. E. Oelling's, for he has swept away all useless parts, reducing the matter to the simplest expression. In this pump the valve controlling the rise and fall of the mercury is operated by hand, as an automatic valve complicates the apparatus. To operate the mercury pump the Packard pump is the best. It is well designed, well built, durable and efficient. All mercury pumps give off mercury vapor. As this vapor in a tube is injurious, it should not be allowed to get there. To prevent it, the glass tube connecting the vacuum tube with the pump should be filled with the metal foil used by gilders. There should be a plug of glass wool above and below. As the vacuum rises in a tube Geissler effects show themselves in the pump when the current is used for tuning the terminals. Although the appearances are very beautiful when the room is dark, they are, like some other beautiful objects, a cause of misfortune. They liberate water vapor, which, entering the tube, lowers its resistance. If the current is kept on during the additional pumping required to remove the water vapor, in ignorance of the cause of the lowering of the vacuum, the terminals will become so exhausted before the proper degree of vacuum is reached again, the tube will be dull. If a tube cannot be exhausted in a short time, the result will not be good on account of terminal exhaustion. To prevent water vapor from entering the vacuum tube, a platinum wire should be sealed into the tube leading to the pump. The point where the wire is inserted should be well within the hot oven, that the Geissler effect may stop near the vacuum tube. The wire should be grounded.

Probably Crookes was the first to make a good vacuum regulator by placing caustic potash in a small bulb connected with the vacuum tube. Such regulators work with heat, either from a spirit lamp, a gas jet or a wire heated by a low-voltage current. When attempts were made to operate them by the same high-voltage current used to excite the X-light tube, it was found when the resistance of the tube was high it was impossible to get any current through the regulator. That is, under the conditions when there was most need of the regulator it would not work. Therefore, in 1896, a regulator was designed in which the chemical was mixed with a conducting powder. This arrangement reduced the resistance of the regulator by forming minute spark-gaps throughout its substance, until the current would go through it at all stages of the vacuum. Such a regulator is shown in Plate 76, Figure 1. It keeps the vacuum at any point determined by the length of spark-gap in the circuit. The regulator is as efficient as the more recent and elaborate ones in which the high resistance is overcome by having the discharge take place in a supplementary bulb with a lower vacuum, which is attached to, but does not communicate with, the X-light tube. It has the advantage of not being patented. Since Trowbridge has advanced the theory that X-light is produced by the heat of the dissociation of water vapor at the target, and not by the heat of impact of the sub-atoms of the cathode stream as stated in these notes, water-vapor regulators are of more interest. Therefore one of this type has been chosen for attachment to the tube illustrated here, though a number of men prefer the oxygen regulator -Note 23, February 9, 1898-, while others like the hydrogen regulator -Note 79, December 20, 1899-, or the nitrogen regulator -Note 96, May 30, 1900-. The inter-molecular regulator -Plate 25, Figure 52, Note 50, February 15, 1899, and Plate 27, Figure 57, Note 62, April 26, 1899-, whether operated by heat or electrolytically, has received little attention in this vicinity. In regard to regulators of any type, however, we are still in the condition described in Note 119 -March 9, 1901-, little advance having been made toward restoring the pristine brilliancy of a tube, though as the power of generators is increased, such advance is to be desired. With all regulators controlled by a spark-gap in a high-voltage current there is a disagreeable snapping noise from the spark when the regulator is in action. This noise may be stopped by placing the spark-gap in a glass tube like the one figured in Note 112, and used to stop the greater noise of the main spark-gaps.

The special form of tube shown in the illustration accompanying this present note was designed by Mr. John O. Heinze, Jr., who modified the capillary spark-gap of Mr. W. S. Andrews for this purpose. He expanded the central part of the tube because it diminished the risk of the tube cracking from the heat of the discharge.[124]

LENGTH OF X-LIGHT TUBES

The earlier X-light tubes were short, generally not over ten centimetres. As generators with higher potentials became more common, the tubes were made longer. The increase in length diminished leakage around the tubes. At the present time makers vary in regard to the length of the tubes they send out. Many still furnish short tubes, while others make them twenty or more centimetres long. The length of the one shown in the figure -fifty-six centimetres- will no doubt be considered excessive.[125]

DIAMETER OF X-LIGHT TUBES

The early tubes had a diameter of from four to seven centimetres. In this respect there has been a general improvement. The tendency at the present time is toward a globular bulb about seven to ten centimetres in diameter, though bulbs as large as sixteen centimetres are sometimes made. This increase in size has been due to the recognition of the need -pointed out in these notes- of storage capacity to prevent the vacuum from falling quickly in use, thus making

[124] This expansion is not important. Refer to Note 175, Plate 136, Figure 2.

[125] Refer to Note 175 for a design for an X-light tube.

the light of too long waves to be useful. There are certain advantages in still further increasing the storage capacity to retard the coming on of a low vacuum. Therefore, the idea of a supplementary bulb, invented by the French in 1896, to supply a source of fresh gas to prevent the vacuum rising in use, may be employed for another purpose, that just mentioned, because in this way the capacity is enlarged without increasing the diameter of the bulbs. As a bulb of ordinary size has to bear an atmospheric pressure of over a ton, while at its thinnest parts, through which the light from the target comes to the patient, the glass should not be over forty-three one-hundredths of a millimetre, the advantage of not increasing the size of the bulb is apparent. Another way is to make the bulb oval, using longer and larger tubes for the ends, for this increases the storage capacity without destroying the symmetry of the tube or increasing the size of the thin part of the bulb.

LENGTH OF TERMINALS

The early tubes had the stems of the cathodes short, about two centimetres in length, and wrapped in glass. It was thought this construction gave more X-light by causing the electricity to be discharged from the front surface of the cathode. When wandering in a wilderness of obscure phenomena the best way to get out is to push each effort to the extreme. Therefore a cathode was made in which not only the stem, but the entire surface of the back of the cathode, was coated with glass. The stem and the back of the cathode were made of platinum, uranium glass being melted on to it. The face of the cathode was made of aluminum as usual. Such a construction offered no particular advantages sufficient to offset the extra cost. Therefore in future designs all idea of confining the discharge to the front of the cathode by short stems and glass wrappings was abandoned. Tube-makers have not taken advantage of these experiments, continuing to supply tubes with cathodes having short and slight stems, wrapped in glass to support them, thus making the tubes very delicate. Powerful currents are fatal to such tubes. Having found by experiment the cathode stem might be of any length, and bare, without injury to the tube, long stems were used when the cooled target tube was constructed, because while it was important to have the tube long, it was also desirable to keep the anode end short for mechanical and financial reasons. When the tube, shown in Note 1, was constructed, there was no difficulty in making the face of the target cold, however long the tube of the target might be. As it was afterward found the only part of the outer tube which needed to be of platinum was the end near the face and a short piece where it was sealed into the glass, the balance being made of copper or of silver, there is no longer any reason why the length of the arms of any type of tube cannot be the same.[126] As a tube in which the bulb is in the middle is more symmetrical, this type has been chosen for the illustration accompanying this note. Aside from the increased storage given to tubes by increasing the length and diameter of the arms, the length is an advantage, as it gives a better opportunity to hold

[126] Refer to Plate 131, Figure 3, Notes 171 and 175.

the terminals in line. This is especially the case with sliding terminals. This consideration alone is sufficient to warrant such a construction.

SINGLE OR DOUBLE FOCUS TUBES

Vacuum tubes are by English-speaking men generally called Crookes tubes, whatever their form; by Germans — Hittorf, Geissler, Plücker, Hertz or Lenard tubes. As usual in historical matters the Germans are more nearly right, for much work had been done before Crookes, though as not one of the men mentioned invented vacuum tubes, there is no reason why they should, as a class, be called after any of them. In those tubes where the cathode stream is brought to a focus on a piece of platinum, there is more reason why they should be called Crookes tubes, for Crookes appears to have invented them. The modification of the Crookes tube with two concave cathodes, which Roentgen described in his paper of March 9, 1896, appears to have been new at that time and might well bear his name. Roentgen tubes are, however, not required even for alternating currents. Besides, alternating currents use up a tube faster for the amount of light yielded, therefore at the present, until we learn how to easily keep a tube youthful, such currents are not desirable. Moreover, at the present time it is not as easy to control the quality of the light produced by a tube excited by a high-frequency current as it is where the tube is lighted by a coil of the type figured in Note 137. For these and other reasons, the type of tube chosen for the illustration of the paper is the Crookes or single focus.

Electrical Review, May 3, 1902.

NOTE 138 A—SOME CONCLUSIONS FROM EXPERIMENTS ON GUINEA PIGS WHICH ARE OF IMPORTANCE IN THE TREATMENT OF DISEASE BY X-LIGHT

Several series of experiments on guinea pigs with X-light have been made. A few of the results have been reported in this journal. In the present note will be given some conclusions from the experiments which are of importance in treating disease by X-light. Roentgen showed the visual and photographic intensity of X-light varied as the square of the distance. Before X-light could be used intelligently as a therapeutic agent it was necessary to learn by experiments on animals whether its effect upon the tissues varied in the same way. The experiments showed it did. The bearing of this observation on the treatment of internal disease is more important than at first appears. It proves the source of X-light should be at a distance, not within a few centimetres, as is the universal custom now when using X-light for therapeutic work. Unless the distance between the exterior of the patient and the seat of the internal disease is small relatively to the distance between the nearest surface of the patient and the tube, the healthy skin and superficial tissues will be subjected to a much stronger radiation than the internal diseased organs. This observation points to the necessity of using much more powerful apparatus than is generally employed, because with the source of X-light at a distance the strength of the radiation striking the diseased tissue is slight; the length of exposure must, therefore, be long.[127] The next matter is the kind of X-light to be employed.[128] General opinion considers the proper radiation for therapeutic purposes to be that from a tube of low resistance, because that is the kind that burns. The experiments on guinea pigs showed all forms of radiation from vacuum tubes which could be classed as X-light[129] could burn, produce abortion and death. Therefore, as injurious effects can be produced with any form of X-light, we should learn to use, without injurious effect, that suited for the purpose. The kind must depend upon the seat of the disease to be treated. For superficial diseases the radiation from a tube of low resistance should be used. There are two reasons. This kind of X-light is most absorbed by these tissues; therefore the energy is used to the best advantage while the underlying healthy tissues are exposed to less stress. Second, with any given generator the amount of electrical energy which can be efficiently used in a tube of low resistance is far greater than the amount we can convert into X-light in a tube of high

[127] Refer to Notes 166 and 167 for further illustrations on this important principle, and to Note 177 for restatement.

[128] Note added 1903. — The proper kind of X-light to be used in therapeutics is that which will be most absorbed by the diseased tissues as far as the situation will permit. In regard to the electrical energy used in a tube, the statement made in this note must be considered with that mentioned in Notes 30 and 63; namely, that of the total energy sent into a tube, only a small part appears in the form of the short waves of X-light. Most, necessarily, is converted into heat and ordinary light. The lower the resistance of the tube, the greater the proportion of long waves.

[129] Refer to Note 176 for the therapeutic uses of radiations from a vacuum tube which are not X-light.

resistance. This is hard to believe, for a high-resistance tube appears to be giving a light many times as brilliant, but experiments in pumping tubes prove as the exhaustion goes on the amount of electricity which any given generator can send through a tube diminishes. One reason why in these notes tubes have been always described as having a high resistance rather than as having a high vacuum has been to keep this fact in mind. Because it has not been recognized, we have gone astray, supposing the light that burnt was that from a low tube, and in consequence thought this was the light required to produce therapeutic effects. It is a question of quantity as well as quality. In treating internal diseases, radiation from a tube of high resistance should be used, because this light being less absorbed by the superficial tissues, they are less affected relatively than with a radiation which they absorb to a greater extent; also, because this radiation is less absorbed by the superficial tissues, more is available for affecting the internal organs. Perhaps as important a conclusion as any from the experiments is this: Powerful apparatus is needed, and experimenters who are working hard to design such apparatus should be encouraged. Their results should not be condemned because the photographic results in the hands of a few have been uncertain and less satisfactory than those obtained with old-fashioned coils and static machines. An investigation showed the fault was not in new and powerful types of generators, but with the tube-makers.

Boston Medical and Surgical Journal, April 24, 1902.

NOTE 139 — NON-RADIABLE CASES FOR X-LIGHT TUBES[130]

Experiments have already been reported which proved that X-light could make animals blind and kill them. Therefore it is a dangerous agent to use without proper precautions. Some of these have been mentioned in earlier notes, but as they are being constantly neglected they will be stated again in a group. First, The X-light tube should always be used in a non-radiable case from which no X-light can escape except the smallest cone of rays which will cover the area to be examined, treated or photographed. Second, The fluorescent screen should be covered on the side nearest the eyes with a sheet of heavy lead glass one centimetre thick, because the fluorescent salt allows much of the X-light to pass through it unchanged. Third, All parts of the fluoroscope except the screen should be heavily painted with non-radiable paint.[131] Fourth, The physician should wear spectacles of lead glass one centimetre thick.

NON-RADIABLE CASES FOR X-LIGHT TUBES

It seems hopeless even at this late date, when so much is known about the possibilities of injury from X-light, to get others to use an X-light tube entirely enclosed in a non-radiable case, because of the supposed inconvenience of a box, therefore the type shown in Plate 77, Figures 1 and 2, is of the semi-enclosing type, like

[130] Better apparatus is illustrated in Notes 143 to 162.

[131] Refer to Note B for a description and illustration of the first non-radiable cryptoscope with glass covering to the screen to protect the observers' eyes. Reprinted from the International Dental Journal, July, 1896.

the one shown in Note 36, August 17, 1898. The case is of the proper size for the tube illustrated in Note 138. The front is polished lead glass, three centimetres thick, to allow the tube to be examined by light of ordinary wave-length to which the glass is transparent, though it absorbs the X-light on account of the great number of sub-atoms crowded into the atoms of lead of which the glass is largely composed.[132] As it is desirable always to have the glass front toward the observer, there is a hole in the top and another in the bottom of the case for X-light to escape through when it is desired to place a patient in horizontal position with the tube above or below him. When not in use the holes are covered with non-radiable slides. The criticism was made that these glass fronts would be too expensive, therefore in a later note -94- a box without glass was illustrated which entirely enclosed the tube. Continued experience during five years of experimental work with powerful apparatus has shown the glass front is so convenient as to outweigh the cost, about five dollars; therefore it is used in the tube case shown in Plate 77, Figures 1 and 2. The whole case is coated on the inside with a non-radiable paint, white lead in japan, which dries so quickly six coats can be put on in a day. The test of the number required is to expose a photographic plate in contact with the outside of the case. If the plate is not fogged in seven minutes, the coating is sufficient. The tube case should slide on a vertical support through a range of one hundred and seventy centimetres. It should have a horizontal movement of one

[132] Consult Notes 109 and 109 A.

metre; there should be a joint to allow the tube case to be moved in a vertical arc whose plane is parallel with the long axis of the tube, and another which will allow a similar movement in a plane parallel with the short axis of the tube. These movements are essential, for the axis of the central ray of the cone of X-light escaping from the case must always be normal to the plane of the photographic plate or fluorescent screen, otherwise there will be distortion of the image. The great importance of these movements in a vertical arc is well shown in the illustrations. The tube box is in two parts, one telescoping into the other. In Plate 77, Figure 2, the top is being removed. This construction utilizes the weight of the top piece to hold the tube from moving. The two pieces have slots in each end that allow free passage to the ends of the tube. The slots are lined with soft rubber to furnish cushions for the ends of the tube to rest on. The wires leading from the generator are held in insulating collars which are shown in Plates 77, 88, Figures 1, 2, 3. On the ends of the leading wires are spiral springs of piano wire which slide loosely over the terminal wires of the ends of the tube -Plate 88, Figure 3-.[133]

At the present time it is practical to make instantaneous pictures of the moving organs in the human chest, provided Pupin's idea of employing a fluorescent screen in contact with the photographic plate is used. A sheet of celluloid coated with photographic emulsion is better than a glass plate, as this allows two or more

[133] Refer to Note 157, Plate 115, Figures 1 and 2, for better methods.

fluorescent screens to be used.[134] A single screen allows part of the X-light to pass through unchanged. A single screen makes the developed image blotchy. More than one screen is therefore better, because the time of exposure is shorter and the blotches are less apparent, for the bright places on one screen usually correspond to darker places on the others. All screens blur the image and should only be used where fine detail is not required. A tube often needs a little preparation to get the light suited for an instantaneous exposure; therefore a tube case needs an instantaneous shutter, for in this way after the tube is in the proper condition the shutter can be closed while the photographic plate is put in place: then by pressing and releasing a bulb the shutter is opened, the plate exposed to the most suitable radiation and the shutter closed. The tube case is provided with two of these shutters, one of which can be attached to either the top -Plate 77, Figure 2- or the bottom of the tube case. The second is used on the front of the tube case when it is desirable to photograph a patient's chest in an upright position, Plates 78 and 79, Figures 4 and 5, Note 140. The tube case, therefore, has two glass fronts, one of solid glass, Plate 77, Figure 2, to act simply as a window; the other with a hole in the middle, as shown in Plate 77, Figure 1, for the escape of the required cone of X-light. This hole is covered by the shutter when the X-light is to be cut off. With the shutter over

[134] Kunzite phosphoresces for several minutes after exposure to X-light -Baskerville-, and therefore it may be useful as a material for coating photographic intensifying screens.

the opening the tube can still be seen through the glass around it. The form of shutter chosen for illustration is a simple one, because the object is to call attention to a principle which, as the power of X-light apparatus increases, will come into use. Better shutters[135] might have been selected, for any of the many beautiful ones used in ordinary photography will answer if made of non-conducting and non-radiable material. The one here illustrated is of wood pivoted on a wooden pin and operated by a rubber bulb held in the hand, air being forced in and drawn out of a hard rubber cylinder, whose piston, of the same material, is attached to the shutter. The shutter should lap over the largest opening in the tube case about fifteen millimetres, to prevent the escape of X-light. It should be lined with white lead in japan until non-radiable. The edges of the hole in the tube box should be coated in the same way on the side next the shutter. In all the illustrations the tube is placed with the radiant area on the target at one metre from the photographic plate or fluoroscope. This is a good standard distance. It is of some importance to have a standard distance, as then the eye gets accustomed to definite sizes of images of the human organs. In this way an abnormal size is more easily detected. Apparatus which requires a less distance than one metre between the target and the photographic plate is not satisfactory. — Electrical Review, June 14, 1902.

[135] A better shutter is illustrated in Note 149, Plates 101, 102, 103, Figures 2, 3, 4, and 5 A.

NOTE 140 — SOME OTHER APPARATUS NEEDED IN THE MEDICAL APPLICATIONS OF X-LIGHT

The coil as arranged in the illustrations to Note 137 was not intended particularly for medical use, therefore in the present note the necessary changes will be described and illustrated.

ARRANGEMENTS OF SPARK-GAPS

In examining a patient by X-light it is of prime importance to have the light under the control of the physician without his losing sight of the image on the fluorescent screen — Note 112. This requires mechanism by which the spark-gaps can be controlled at a distance from the coil. Dr. Williams did this with a large static machine by bringing cords over pulleys attached to the ceiling.[136] The plan shown here is a mechanical modification of his idea to adapt it to a coil and make the apparatus portable. Plate 81, Figure 6, shows a seventy-one-centimetre coil with suitable spark-gaps for medical use. The details of a spark-gap, when this is taken apart for transportation, are shown in Plate 82, Figure 7. The handles -H and H', Plate 81, Figure 6- are within easy reach of the physician's hands while he is examining a patient -Plate 83, Figure 8-. The distance of these handles from the coil may be varied by sliding the rods more or less into the hollow angle sockets. The rods forming the spark-gap controlling mechanism are ordinary birch dowels three-quarters of an inch in diameter which can be bought for one cent each. The supporting arms swing in arcs whose planes are horizontal.

[136] Scientific American, June 17, 1899.

There is a piece of wire cable -W-, Plate 81, Figure 6, which brings the current from the brass ball -B- to the brass cap forming the front of the glass spark-gap tube. To this cap is attached the socket -T- into which the cable going to the X-light tube is inserted. To counterpoise the weight of the cord and handles, a counterweight -W- is attached to the brass ball -B- by oiled silk cord. Otherwise the mechanism of the spark-gap is that described in Note 112, which should be consulted. E is a tube connected with an aspirator to remove the nitrogen compounds produced at the spark-gaps.[137] Plates 84, 85, 86, 87, Figures $8\frac{1}{2}$, 9, 10, and 11, show the spark-gaps in use while photographing a patient in different positions.

EXAMINATION TABLE[138]

This is a simpler form of the one illustrated March 9, 1901. The table -Plates 80, 81, 83, 85, 86, 87, Figures $5\frac{1}{2}$, 6, 8, 9, 10, and 11- moves on large wheels to allow any part of a patient to be easily brought between the physician's eyes and the X-light tube, while he remains in proper position to control the light by means of the break and spark-gaps. This examination table is provided with a canvas stretcher because it has been clearly shown by Williams that examinations can be made on the same stretcher that is employed at the Boston City Hospital to bring the patient from the wards to the X-light laboratory. Instead, however, of using his plan of a stretcher on fixed supports, it is

[137] Boston Medical and Surgical Journal, April 25, 1901.

[138] For a better form refer to Notes 155 and 156.

best to attach it to a rolling table for the reasons given. Plate 85, Figure 9, is a general view of the apparatus used with a seventy-one-centimetre coil whose spark-gaps -Plates 81, 82, Figures 6 and 7- are arranged for medical work. The patient is in position for photographing a stone in the bladder. For this procedure the patient's feet should be higher than his head that the stone may fall away from the pelvis. Note 117. One end of the stretcher is therefore raised by means of toothed bars pivoted to the ends of a notched bar holding the ends of the stretcher poles. The canvas is slack, for this allows the abdomen to be more pendent. In those cases where a slack canvas is undesirable, it can be made taut by turning one of the bars supporting the canvas, a ratchet holding the bar from turning back.[139] When it is desired to bring the patient to a horizontal position, the bar connecting the two toothed bars is pressed, to release the latter, while the stretcher bar-handles are firmly grasped. This mechanism allows the movement to be made by one man. The stretcher can be entirely removed, the thin top of the table serving as a support for a patient in a sitting position, Plate 86, Figure 10, or while reclining, Plate 87, Figure 11. Plate 88, Figure $11\frac{1}{2}$, shows a convenient support for use in connection with the examination table. It consists of two square pieces of hard wood, each one metre long, sliding in sockets which can be clamped to any part of the frame of the examination table. These pieces of wood are connected by canvas. The distance between them can be varied from the entire width of the ex-

[139] For a later method refer to Note 155.

amination table, as in Plate 86, Figure 10, to a narrow strip, as in Plate 83, Figure 8, by rolling the canvas about one piece of wood; Plates 78 and 79, Figures 4 and 5, also show the apparatus in use.

APPARATUS FOR SUPPORTING A PHOTOGRAPHIC PLATE

In earlier notes it was said a photographic plate which was to be used in making a picture by X-light should be contained in a thin metal holder to protect it from breakage by the weight of a patient and from perspiration and urine. The importance of allowing no unnecessary X-light to strike the plate was pointed out, and figures were given of a plate-holder which accomplished these results. The plate-holders shown in the illustrations accompanying this note are those already figured, as longer use has proved them to be satisfactory. The apparatus for holding them in any position in regard to the patient is also the same as that of earlier notes. The present illustrations and descriptions are given to show its universal character. That an apparatus with so few parts should be capable of such varied use is interesting. As yet, after several years, no case has been seen where the photographic plate could not be firmly held in proper position by this universal plate-holder clamp. The fundamental support is the piece C, Plate 89, Figure 12, which can be clamped to any part of the side or end bars of the examination table. The other parts are, — three square brass tubes with sockets at their ends provided with milled-head screws; a plate, A; a wooden sheath, PS and B.

The plate-holder slides into this wooden sheath, which is a mahogany board thick enough to make a firm support for the plate-holder and for the attachment of bars, which hold the pivot plate -A, Plate 89, Figure 12-. Around three sides of the board is a brass rim forming, in connection with it, an open scabbard for the plate-holder. The small cut in Plate 90, Figure 14, shows the front of the wooden plate-holder sheath with an 8 by 10 plate-holder partly withdrawn. A number of sheaths are required. The best sizes are those which will take plate-holders for plates 8 by 10 and 14 by 17 inches. Each sheath has on its back two bars to allow the same plate -A, Plate 89, Figure 12- to be used with any plate sheath. A milled head, by exerting pressure, prevents the sheath from moving. This milled head is not a continuation of the axis on which the plate sheath turns, as that arrangement was found not to clamp firmly without the application of great force.[140] The largest milled head shown in Plate 89, Figure 12, allows the sheath to turn in an arc whose plane is perpendicular to the page and at right angles with the other arc. Plate 89, Figure 12 -P-, is a 14 by 17 plate-holder. Plate 90, Figure 14, shows it open, exposing the photographic film and fluorescent screen. Plates 78, 79, 80, 85, 86, 87, 91, Figures 4, 5, $5\frac{1}{2}$, 9, 10, 11, 15, illustrate a few of the positions in which this apparatus will hold the photographic plate. All these figures show clearly how necessary it is to have the tube-case and plate-holder supports with universal movements, that the central

[140] To more clearly understand this principle, turn to the Plate 113, Figures 5 and 6, Note 156.

ray of the cone of X-light escaping from the tube box shall strike the photographic plate normal to its surface. To impress this necessity is one of the reasons why so many illustrations have been made. — Electrical Review, June 21, 1902.

NOTE 141. — SOME REMARKS ON CAPACITY AND POTENTIAL IN COILS USED FOR EXCITING X-LIGHT TUBES

One of the most interesting features of the coil described in Notes 112 and 137 was the ability to alter the character of the surges. Apparently this is a matter not yet understood. Therefore, even at the risk of repetition, it will be reconsidered in connection with a few illustrations which show how to arrange a coil. In coils prior to the one illustrated in Note 112, where the terminals were separated to their furthest limit, the full potential and capacity of the coil was available. When the terminals were near together the capacity was unchanged, but the potential of the current in the X-light tube current was reduced. In this coil the capacity of the surges used to excite the tubes can be varied within wide limits, by the Leyden jars of different capacity in the secondary current, by the arrangement of rods which form the terminals of the coil, by the arrangement of the spark-gaps in the tube circuit. Plate 92, Figure 16, shows a seventy-one-centimetre coil with the rods -PP- arranged to give the full capacity of the coil. They touch the last balls, therefore all the coils of wire are in use. The Leydens are of one-gallon capacity, which is as large as is generally useful with this coil.

Large jars cut down the potential, as there is not enough current to fill them with sufficient rapidity. CC are the wire loops connecting the coils of the secondary of each of the three sections into one continuous coil of wire. The rods PP are hollow, other rods terminating in the brass balls SS, sliding within them. W is a fine copper-wire cable connecting the inner coating of the jars. This is made taut by the weights hanging above the jars. If an X-light tube were placed in connection with the terminals of the coil thus arranged, it would be broken by the strain if its resistance was high. To avoid this danger the coil should be arranged as in Plate 93, Figure 17, where the Leyden jars and the whole number of coils in the secondary are used as before, but the internal rods are drawn out from the hollow rods -PP, Plate 92, Figure 16- until the distance between the balls -SS, Plate 92, Figure 16- is but a few centimetres. The potential strain on the tube is therefore limited to the length of the spark-gap S, Plate 93, Figure 17. In Plate 94, Figure 18, the rods PP are pushed toward each other, and the section bands -CC, Plate 93, Figure 17- are removed, thus making all the turns of wire in the secondaries of the two outer sections of the coil inoperative. The Leydens are also removed. In this way the capacity of the coil is greatly reduced.

If we arrange the rods as shown in Plate 94, Figure 18, but leave the bands CC, Plates 92 and 93, Figures 16 and 17, then a condenser effect is obtained from the coils of the two outer sections, yet the potential of the coil is still low. It has been clearly shown in former notes that to excite properly an X-light tube for fluoroscopic work the electricity should be stored in a reservoir, allowing it to rush through the tube in such amounts as are best suited to the size of the cathode and the condition of the tube, and at such intervals as will allow the longest periods of rest to permit the tube to recuperate between the surges. On account of the present importance of this procedure, coils should be constructed to allow it to be employed.

Electrical Review, June 21, 1902.

NOTE 143 — ON THE IMPORTANCE OF KNOWING THE POSITION OF THE SOURCE OF X-LIGHT AND OF AUTOMATICALLY RECORDING IT ON THE NEGATIVE WHEN THE PHOTOGRAPH IS TO BE USED IN MEDICO-LEGAL CASES

In Note 117, March 9, 1901, it was said the central ray of the beam of X-light escaping from the tube box and used to illuminate the screen or the photographic plate should strike these normal to their surfaces; an instrument should be attached to the tube box or other convenient support, for finding where the central ray struck the screen and automatically recording on the negative the position of the source of X-light. This instrument, to which the name central ray, distance and position finder was given, was invented to aid Dr. F. H. Williams in his classical work on the medical applications of X-light. He had found, in making examinations of the chest with the fluoroscope, it was essential to place the tube in a definite relation to the patient to enable records to be kept which could be compared. This plan of Williams must always remain of fundamental importance. Without it X-light examinations are unscientific, because lacking in precision. Williams' method of procedure was to use a plumb line, a cord with a weight at each end. This left no record on the negative. -Refer to Figures 69 and 70, of the second edition of his work, Roentgen Rays in Medicine and Surgery, where the plumb lines are shown above the plate and hanging down on both sides of the patient.- To obtain a record on the negative of the source of X-light he placed a metal washer on the paper envelope containing the photographic plate, adjusting the tube by means of the plumb lines and a measuring rule until the source of light was under the washer. This method, while sufficiently accurate, if carefully carried out, requires more time than the method of a central ray marker, is most applicable to a patient in a horizontal position, does not show at what angle the central ray strikes the photographic plate, or the distance of the source of X-light. To avoid distortion of the image and to allow for it, both the angle and the distance should be known. A glance at the two figures mentioned will show the rule of keeping the central ray normal to the plate was not appreciated, though the departure is slight and would not be worthy of mention except to call renewed attention to the principle. As the method described in Note 117 is too simple to be lost sight of, it is described again, with more figures. The method is particularly applicable to medico-legal cases, as false information can readily be given by means of X-light negatives, on which account many judges justly object to such photographs being used as evidence. Before X-light negatives can be safely used for this purpose, the principle of automatically recording on the negative the distance and direction of the source of X-light and the angle at which the central ray struck the photographic plate must be adopted. There are many ways of carrying out the idea, but none more simple than those illustrated in the paper mentioned. In the figures accompanying the present paper the instrument is attached, as before, to the tube box, for, as the experiments have shown, such a box, from which no X-light can escape except the smallest beam that will cover the area to be examined, treated or photographed, is essential; the tube box is the proper place for the attachment of a number of necessary instruments described in these notes. In Plates 95 and 96, Figures 1 and 3, the finder is attached to a thin disk of wood, which, if coated with aluminum foil, becomes a small Tesla screen when put to earth. As it was shown in the Boston Medical and Surgical Journal for February 14, 1901, and January 9, 1902, X-light could not only burn but kill animals after passing through two plates of aluminum, one of which was grounded, the use of a Tesla screen is not so important as was at one time supposed.[141] The finder consists of a metal tube, instead of a rod as shown in Plate 56, Figure 95, Note 117. The tube is attached to the centre of a disk of pine wood. Outside is a square

[141] Note added 1903. — A Tesla screen can stop charged particles and electrons, which, as shown in earlier notes, can produce burns, whether given off from high voltage apparatus or radio-active substances.

frame of non-radiable metal which has a diameter suitable for the work. In the figures here given, the diameter is four centimetres. As the non-radiable frame is placed at a determined distance from the source of X-light, which is the spot on the target struck by the sub-atoms of the cathode rush, it is evident if this distance is known we can tell from the diameter of the shadow on the screen or plate how far they were from the source of X-light, for this starts as a spherical wave which spreads in all directions. For example, if the non-radiable frame is kept at a constant distance of twenty centimetres from the source of X-light, and its image on the screen or negative is eight centimetres in diameter, then the distance of the source of X-light from the screen or negative was forty centimetres. If, as in Plate 97, Figure 4, the image of the square is free from distortion, and the image of the central ray marker is a circle, the source of light was directly under that circle and the central ray struck the plate or screen normal to their surface. If, as in Plate 97, Figure 5, the image of the square is distorted, the central ray did not strike the surface normally. It is obvious the frame need not be a square. In making examinations with the cryptoscope, the central ray position and distance finder is of particular value also, for showing the position of the source of light, and in avoiding distortion of the shadows of internal organs. Plate 96, Figure 2, shows another method of mounting the central ray, distance and position finder. Other methods will be figured later.[142] The instrument can be placed in front or below the

[142] Refer to Note 149, Plate 101, Figure 2.

tube box, when the patient is in front or below the tube. As illustrated here, the patient is supposed to be in a horizontal position above the tube. The tube box to which the instrument is attached is a form of those shown in Note 36, August 17, 1898; Notes 48, 94, 112, 115, 119. As after seven years a few realize X-light is as important to a physician as a microscope, there is good reason for illustrating improved forms of apparatus mentioned in earlier notes, for efficiency and convenience in use now far outweigh considerations of first cost, which have so far been one of the obstacles experimenters have encountered in their attempts to get suitable apparatus used. This is particularly true of tube boxes, which, being necessary, though even now used by but few, will be described in more elaborate forms, with attachments which are calculated to make X-light examinations more precise and rapid. It is also true of cryptoscopes; of diaphragms for reducing the diameter of the beam of X-light escaping from the tube box; of shutters for making rapid photographic exposures conveniently, when powerful apparatus shall be the rule instead of the exception. One such shutter was figured in Note 119, and an improved form is illustrated in the present note; with an adjustable diaphragm, of a more convenient form than those previously shown. It takes the place of the iris diaphragm, applied to X-light examinations in 1896, but used less than was expected, both on account of its large size, when made of non-radiable material, and because the form of its opening — a circle — while well adapted for shaping the beam of X-light escaping from the tube box, when used for therapeutic work, is not the best shape for examinations with the cryptoscope or for photography, where a rectangular opening is necessary in order to protect the patient from all the X-light except what is needed to cover the plate or screen. If a cone of X-light large enough to cover a rectangular screen or plate is used, it is obvious all around the screen or plate there must be X-light which is of no use and is injurious, for it illuminates the tissues and blurs the image on the screen or plate. It is, therefore, best to use a shutter having a rectangular opening, and, in therapeutic work, to insert in this opening or in front of it a small iris diaphragm. These matters will, however, be considered in more detail when describing shutters and diaphragms.

Electrical Review, March 7, 1903.

NOTE 144—ON THE IMPORTANCE OF REFLECTED X-LIGHT IN THERAPEUTICS

Roentgen -December, 1895- reported that some metals, particularly zinc, reflected X-light in an irregular manner. Tesla published a table showing the proportions of transmitted and reflected light. He confirmed Roentgen's statement in regard to zinc. Advantage was taken of these observations to make zinc cones in which the light went around a corner for treating diseases of the mouth. To prevent any X-light from escaping from the tube, except through the open end, the outer wall was made of lead. This construction allowed the tubes to be sterilized by heat. In use the large end of the tube was attached to the tube box, so that no X-light could escape into the room except what went out through the small end of the cone. There were several ends of different diameters. The plan is useful for treating other parts of the body.

Electrical Review, March 14, 1903.

NOTE 145 — ON THE DEVELOPMENT OF THE CRYPTOSCOPE, USUALLY CALLED THE FLUOROSCOPE

Salvioni, Medical and Surgical Academy of Perugia, February 8, 1896, placed the fluorescent screen, used by Roentgen, at one end of a tube, which had an opening for the eyes at the other. He called the instrument a cryptoscope. Professor W. F. Magie, American Journal of Medical Science, February 7, 1896; E. P. Thompson, daily papers, February 13, 1896, — did the same thing in America, where the instrument was called a sciascope.[143] Edison used tungstate of calcium for the fluorescent salt, and called the form of instrument he designed, a fluoroscope. If we follow the usual custom of science, we should use the first name.

Rollins -Electrical Review, February 8, 1899, Boston Medical and Surgical Journal, January 31, 1901- added a sound chamber to the cryptoscope, enabling the sounds of the heart and lungs to be heard while their shadows were being examined on the fluorescent screen, calling the instrument a seehear. Having found animals could be made blind by X-light, he advised interposing a screen of heavy lead glass between the fluorescent screen and the physician's eyes, stating most of the X-light passed unchanged

[143] From Thompson and Anthony's work on X-rays.

through the screen of fluorescent salt. He also insisted upon the necessity of making the cryptoscope of non-radiable material, as a means of preventing diffused light from entering. In the present paper attention is called to some details not particularly dwelt upon before. First, it is important to construct the cryptoscope of such material it may be easily sterilized by heat, as it is now constantly used about patients having contagious diseases.[144] The cloth-covered pasteboard or wooden fluoroscopes in use cannot be sterilized by heat, as they would fall to pieces. Therefore, for this reason also the cryptoscope should be made of metal like the cryptoscope shown in earlier notes. The construction of such an instrument, designed to aid Dr. Williams, is shown with some detail in the figures accompanying this note. Plate 98, Figure 1, illustrates the instrument in one of its earlier forms, where it followed the general form introduced by Edison, but had a sheet of heavy glass over the screen, and walls of non-radiable material. On account of the weight of the large plate of glass, more than four pounds, a different construction was adopted, the glass plate being reduced in size and placed at the eye end, as in Plate 98, Figure 2, and its section. To convert the instrument into a seehear, it was only necessary to add the stethoscope, as in Plate 99, Figure 3. To limit the area of the sound chamber, limiting forms were introduced which are clearly shown in Plates 99 and 100, Figure 4 and its section. All stethoscope tubes have been made of soft

[144] Refer to Note B for first non-radiable cryptoscope with a glass plate to protect the eyes, and metal walls to allow of sterilizing by heat.

rubber to get flexibility. Heat has an injurious effect upon this, therefore to enable the whole instrument to be sterilized, the plan shown in the figure was devised. The tubes were made of metal, flexibility being obtained by forming the wire into closed spirals. Plate 100, Figure 5, illustrates the cryptoscope used as an X-light beam-finder. — Electrical Review, March 14, 1903.

NOTE 147 — X-LIGHT AS A MEANS OF IDENTIFYING CRIMINALS[145]

Several systems of identifying criminals are in use founded upon measurements. I have proposed another based upon X-light photographs of the criminal's bones, those of the hands and feet, for example. Now manufacturers are selling X-light apparatus for two hundred dollars, the system is worth attention, as it requires little time to carry it out. With the present systems it is customary to make a photograph of the criminal's face; therefore carrying the photographic process to his bones would be easy, for the photographer could be taught to do this in a month. The time required would be short, as twenty seconds is sufficient for the photographing of the extremities by X-light with ordinary apparatus. An examination of a large number of X-light photographs of the hands and feet proved the probability of finding two alike would be very small. When we consider that an X-light photograph shows not only the shape of the bones, but their internal structure, the chances are almost infinite against two being alike. When this method is used, the central

[145] Refer also to Note 147 B.

axis-marker, position and distance finder must be used in order to be sure the source of X-light bears a fixed relation to the plate. An examination of X-light pictures of the same bones taken at intervals of six years showed the differences were too slight to prevent identification in that time. It is not to be expected two photographs taken at long periods apart will be identical, as some diseases are known to change certain characteristics of the bones, but so they do of all the other parts of the body.

Electrical Review, March 14, 1903.

NOTE 147 A—THE EFFECT OF X-LIGHT ON THE CRYSTALLINE LENS

Experiments have been reported in this journal which showed animals could be made blind by X-light. Through correspondence with investigators, who at different periods have worked with X-light, a number of cases have been found where the eyes had grown prematurely old during the investigations. Recently a man was examined who had been exposed to X-light to a considerable extent since 1896. Though he was less than forty years of age, he had given up trying to read even a daily paper. To enable him to see his work comfortably at a distance of forty-three centimetres, it was necessary to provide him with double convex glasses, number twenty-six. With the exception of Professor Trowbridge's great condensers and Tesla's high-frequency generators, the apparatus used in the experiments to help Dr. Williams in his work was the most powerful employed in the production and study of X-light. That injury did not result was due to an early recognition of the dangerous nature of X-light, and to the precautions recommended in earlier papers having been taken. These uninteresting personal matters are mentioned only to give an opportunity to repeat some of these precautions. No X-light should strike a patient except the smallest beam that will cover the area to be examined, treated or photographed. No X-light should strike the observer. Directions for constructing apparatus to meet these conditions have been given. A few points will bear being repeated. The X-light tube must be in a non-radiable box from which no X-light can escape except the smallest beam that will cover the area to be examined, treated or photographed. The box must have a non-radiable diaphragm plate, the opening in which can easily be adjusted while looking in the fluoroscope, until the beam of light is the smallest that will cover the area under examination. The cryptoscope must have a plate of heavy lead glass to absorb the X-light which has passed unchanged through the fluorescent screen, to prevent injury to the observer's eyes. The walls of the cryptoscope must be made of non-radiable material. The patient should be covered during photographic exposures with a non-radiable sheet, exposing only the necessary area. An experimenter who works much with X-light should use a non-radiable face mask, the eyeholes of which are glazed with thick plates of heavy lead glass. In using the cryptoscope, while testing the tube during pumping and tuning, he should not take his hand for examination, but should attach to the cryptoscope a Roentgen gauge and a Williams fluorometer for determining the penetrating power of the X-light and its brightness. The hand that holds the cryptoscope should be protected with a non-radiable covering. During the pumping and tuning of X-light tubes, they should be kept in an oven with non-radiable walls. Most of these precautions are neglected even at the present time, as may be seen by examining the illustrations in the catalogues of the makers of apparatus and in the papers and books of those who are writing on the subject, where open tubes are almost invariably figured. If masks are used to protect patients during the therapeutic application of X-light, they are in many cases made of rubber cloth or other radiable material. If speculas are used in treating the cavities of the body, they are often made of radiable celluloid. Rubber or celluloid to make them suitable must be mixed with heavy metals or their compounds. That inefficient means are still employed to protect patients is partly due to attempts to ignore or disparage the crucial experiments that have been reported in other notes on the effects of X-light on animals. These experiments showed X-light could not only burn, make blind and kill, when all other forms of energy that could produce the results were excluded, but they also proved under the conditions present during the proper use of X-light in therapeutics, other kinds of energy acted so slowly they need not be considered in the light of causes of serious injury to patients. Therefore, attempts to protect patients should consist in protecting them as far as possible from the light itself. Another matter to which attention should be directed is the importance of making all the apparatus used about patients during therapeutic applications of X-light of materials which will allow them to be sterilized. Some of the diseases for which X-light is used are known to be contagious, and while it is generally considered cancer is not contagious, it is an interesting fact that several persons who have been treating this disease by X-light have themselves been attacked. This probably would not have happened if proper precautions had been taken. It is, to say the least, unwise to be constantly treating cancer and other diseases by X-light without regularly fumigating the room and keeping the cryptoscope and other appliances sterile. Great hospitals, in which the necessity for contagious wards is clearly recognized, still consider one room, which is not fumigated, a proper place in which to make not only all diagnostic but all therapeutic applications of X-light, and to make them with apparatus which is not sterilized. In fact, to sterilize the present forms of much of the apparatus in use would be difficult by heat, which is the simplest method. It would appear to be at least reasonable to take advantage of such power as may reside in formalin vapor to fumigate the X-light room every night, and to make the instruments used about patients of such material as will permit heat to be used to sterilize them. Cryptoscopes, see-hears and stethoscopes, light concentrators, light benders and specula which can be sterilized in this way have been described in these notes.

Boston Medical and Surgical Journal, April 2, 1903.

NOTE 147 B — X-LIGHT IN ANTHROPOMETRICAL SIGNALMENT

The time will come when the law will require every person on reaching adult age to be signalized. Meanwhile we know from the researches of Bertillon and others that the anthropometrical department of signalment is the foundation of every valuable method of identifying criminals. Any procedure which will make these measures more exact must be valuable, for already the number of signalments is several hundred thousand in France alone. Every day the chances of making a mistake in identification become greater. The difficulty is not in the first separation, but in the last group, in which the measures are most alike. The ordinary measures taken are, — height, length of trunk, reach, length of head, width of head, bizygomatic diameter, length of right ear, length of left foot, length of left middle finger, length of left little finger, length of left forearm. Of these measures it may be said that they are of value only when they are accurate. It is evident if any of these measures could be taken with double the accuracy now possible, we could identify twice as many persons. This can be done by making X-light photographs of the bones. It is estimated this method at least doubles the accuracy with which measures of the hand can be taken, and by enabling other measures of the feet, besides the length, to be made, it allows at least four times as many persons to be identified as at present, though the real number will be found to be much greater. As X-light not only gives photographs of the dimensions of the bones, but also shows their structure, it is evident for purposes of fine distinction in the final stage of the identification the method is an advance. In cases of bodies burned or decomposed before being discovered, the method would have some advantages over any that has been proposed. In other cases where only parts of the body were found, as, for example, a hand or a foot, the method alone might lead to identification. Apparatus has been designed and constructed for conducting these X-light photographic anthropometric signalments, and described in other papers, as they appeared too technical to interest the readers of a medical journal. The method may interest physicians, as it is a more exact appeal to anatomy as an aid to identification than any yet proposed. Indispensable requisites for making such measures of value are to have the source of X-light at a uniform distance from the photographic plate; to have the plate bear on its face evidence of the direction and distance of the source of X-light and the angle at which the central ray struck.[146] Apparatus for accomplishing these results, to which was given the name orienter, was illustrated in this journal for 1901, and much more fully in Notes on X-light in the Electrical Review. The matter is here mentioned because the apparatus is important to physicians from a medico-legal point of view when X-light negatives are used in court for evidence.

Boston Medical and Surgical Journal, May 7, 1903.

[146] Refer to Notes 117 and 143.

NOTE 148 — X-LIGHT AXIOMS

In earlier notes some principles of importance in the application of X-light to medicine were first stated, illustrations and descriptions of apparatus embodying them being given. A few of these principles which might well be called X-light axioms will be mentioned again, as they are of sufficient importance to be repeated until they are adopted.

First Axiom, No X-light should strike a patient except the smallest beam which will cover the area to be examined, photographed or treated. Second Axiom, No direct X-light should strike the observer. Third Axiom, The physician must be able to make all the adjustments of the X-light without interrupting the examination by removing his eyes from the image on the fluorescent screen. Fourth Axiom, The physician must be able to orient himself in relation to the patient and the source of X-light at all times during the examination without removing his eyes from the image on the fluorescent screen. Fifth Axiom, To avoid distortion the fluorescent screen must be held always, during the examination, with its surface normal to the central ray of X-light. The first of these axioms to be discovered was the most obvious, — the need of regulating the amount and quality of the X-light while making examinations without removing the eyes from the image on the fluorescent screen. Several means were tried: -A- placing a rheostat controlling the speed of the static machine within reach of the observer's hand; -B- altering the distance between the terminals of the X-light tube by an external magnet operated by a lever within reach of the observer's hand; -C- a compound spark-gap in series with the tube and operated by a lever within reach of the observer's hand; -D- a tube in which the Crookes potash regulator was operated automatically by heat produced by electricity and controlled by a lever within reach of the observer's hand; -E- a rheostat within reach of the observer's hand which regulated the current passing through the primary of the induction coil. Soon afterward the importance was realized of being able to orient in relation to the patient and the source of X-light at all times during an examination, without removing the eyes from the image on the fluorescent screen. The best method found was described in Notes 115 and 117, March 19, 1901, and more fully in Note 143, March 7, 1903. Many mechanical modifications of this will no doubt be made, but to be effective they must embody the principle, the statement of which was a valuable contribution to X-light literature. The importance of allowing no X-light to strike the patient except the smallest beam that would cover the area to be examined, was next recognized. The first attempt to embody this idea in mechanism was described and illustrated in the International Dental Journal for September, 1896. The result was an adjustable concentric non-radiable diaphragm plate, which could be centred with the central ray of the source of X-light used to illuminate the patient; the area of the beam being limited by the size of the hole in the diaphragm. The next attempt was to enclose the tube in a non-radiable box having a non-radiable diaphragm. The importance of allowing no direct light to strike the observer was naturally the last to be recognized. The means to prevent this were a non-radiable box with a diaphragm, that the observer might be at the side of the beam of X-light, and the use of a non-radiable cryptoscope, when the examination required him to stand in the direct beam; illustrated in Note 116, February 2, 1901, and described in Note 139, June 14, 1902; again described and illustrated more fully in Note 145, March 14, 1903. Though a certain amount of apparatus constructed in accordance with these ideas has already been described, some improvements are of sufficient importance to be considered in the two or three following notes. — Electrical Review, April 4, 1903.

NOTE 149 — ON THE FORM OF THE OPENING IN THE DIAPHRAGM PLATE OF THE X-LIGHT TUBE BOX AND ON MEANS OF ADJUSTING THE SIZE OF THE BEAM OF X-LIGHT

The opening in the diaphragm plate of the X-light tube box should be rectangular for diagnostic and photograph work, because this is the form of the fluorescent screen and photographic plate. If we use a round opening, the section of the cone of X-light escaping from the tube box is a circle -if the cone is cut at right angles to the axis- as shown in Plate 116, Figure 1. While the patient will be illuminated by the whole cone, it is evident the only part of the illumination which will be useful, will be that included in the rectangular area of the largest plate or screen, Plate 116, Figure 1, which can be enclosed by the circle of X-light S. All the X-light which strikes the patient outside the rectangular area PS is objectionable, for it is unwise to expose a patient unnecessarily, besides the excessive illumination fogs the photographic plate and blurs the image on the screen in two ways. The direct light illuminates the tissues where not needed; the resulting irregularly reflected light in the body helps to conceal the structure of the parts under observation, Note 10, January 5, 1898; Note 94, April 11, 1900. X-light escaping into a room fills it with a potential mist, Note 94, April 11, 1900, which penetrates to the screen or plate in all directions, Boston Medical and Surgical Journal, April 25, 1901, if the ordinary cryptoscope or plate-holders are used. The only way of preventing the resulting diffused illumination from injuring the sharpness of the image on the fluorescent screen or photographic plate is to use the non-radiable cryptoscopes and plate-holders described in earlier notes. Even with these, the injurious effects of the unnecessary light in the direct beam cannot be eliminated. Therefore the form of the illuminated area should conform to that of the fluorescent screen or photographic plate. As the proportions of the length and breadth of the ordinary screens and plates are about four to five, the proportions of the opening in the diaphragm plate should bear the same relations to each other. In the figures a diaphragm plate is shown in which the opening is a square, as the fluorescent screens and photographic plates should have this form, which is recommended to the manufacturers. The principle of the diaphragm plate here shown is as applicable to oblong openings as to squares. If, however, the opening were made longer in one direction than in another, it would be necessary to mount the diaphragm plate on a revolving plate or else to mount the tube box in the same way, either of which complicates the matter. This is another reason for figuring a square opening. To meet the conditions of the first and third axioms, we must be able without removing the eyes from the image on the fluorescent screen to change the size of the opening in the diaphragm plate. As the diaphragm is beyond the reach of the observer, when the tube is placed at the standard distance of one metre, as recommended in these notes, some way of bringing it within reach must be employed. Means have been devised of making this and all other adjustments of the tube and light by electric motors controlled by switches on a consol within reach of the hand, in the way employed in the medical rheostats, already described, but they are too refined to be accepted at present, therefore all the methods which will be illustrated, will be mechanical.

Description of Diaphragm Plate and Adjustment of Size of Opening — Plate 101, Figure 2, is a front view of a diaphragm plate attached to the slide S^2 of the tube box TB. The opening of the diaphragm plate when fully expanded, as shown in the figure, has an area of forty-nine square centimetres. By turning the milled head MH, the size of the opening can be reduced or the X-light entirely cut off. Plate 102, Figures 3 and 4, show the mechanism by which this is accomplished. Each of the diaphragm leaves has a rack -Plate 102, Figure 3-. When the two leaves are superimposed as in Plate 102, Figure 4, a pinion passes through both, and when turned, moves one leaf in one direction, the other in the opposite an equal amount, making the opening and closing symmetrical about a centre. The central portions of the leaves are made of lead plates two or more millimetres in thickness, that the surroundings of the diaphragm opening may be non-radiable. Method of controlling the opening from a distance: The milled head MH -Plate 101, Figure 2- has a square hole in it. Into this hole fits the projection of the spiral spring SP of the regulating handle RH. The regulating handle is supported in any position by the adjustable arm AR. Plate 102 A, Figure 5, is a perspective view showing the parts in position; Plate 103, Figure 5 A, a front view. Method of controlling the position of the diaphragm plate -Plate 101, Figure 2-: A screw S operated by a milled head MH 2 and handle RH 2 supported by the arm AR 2, moves the diaphragm plate transversely to the tube box. Movement at right angles to this in the same plane is effected by a similar handle RH 3 supported by the arm AR 3 and operating the rack R through the pinion P.[147] By means of these handles, the diaphragm plate can be centred with the central ray, making the opening and closing symmetrical about this ray, a matter of importance to be spoken of later. As mentioned in earlier notes, the form of the diaphragm opening when the light is used for therapeutic purposes does not require to be a square, as the diseased areas seldom have that form. The round opening may therefore be useful in such cases. To get an easily adjusted round opening, the iris dia-

[147] This rack should be replaced by a screw.

phragm may be attached to the diaphragm plate. As, however, a mask is used in such cases, the hole in which only exposes the necessary area of the patient, it is adequate to use the square opening, thus saving the extra cost.

Electrical Review, April 4, 1903.

NOTE 150 — ON THE FORM OF THE MOUNTING FOR THE CENTRAL RAY MARKER, DISTANCE AND POSITION FINDER, AND ON THE METHODS OF ADJUSTING THEM DURING AN EXAMINATION WITHOUT REMOVING THE EYES FROM THE IMAGE ON THE FLUORESCENT SCREEN

Axiom 4 stated the physician must be able to orient in relation to the source of light and the patient at all times during the examination without removing his eyes from the image on the fluorescent screen. The apparatus described in Notes 115 and 117, March 19, 1901, and more fully in Note 143, March 7, 1903, enables this to be done. An improved form of mounting is here shown. The central ray marker, distance and position finder is permanently attached to the diaphragm plate, following its movements; therefore, as the position of the diaphragm plate is controlled by the handles RH 2 and RH 3 -Plates 101, 103, Figures 2 and 5 A, Note 149-, it is evident the same handles enable the observer to locate the position of the source of X-light by moving the diaphragm plate until the image of the central ray marker shows as a circle on the screen, as in Plate 97, Figure 4, Note 143. Then the source of light is under that circle in a direct line -Note 117, 1901, and Note 143, 1903-. As the diaphragm plate is mounted with the opening concentric to the central ray marker, it is evident the beam of light is concentrically disposed about the central ray. The method by which the physician is always able to keep the fluorescent screen with its surface normal to the central ray, as it must be to avoid distortion of the shadows of the patient's organs on the screen, is simply to be sure the image of the central ray marker on the screen is free from distortion, and this soon becomes instinctive. Where it is desired to have the tube in a direct line under some selected spot of the body, as recommended by Williams -page 66 of Roentgen Rays in Medicine and Surgery-, a lead ring about fourteen millimetres in diameter should be placed either on the patient's skin or clothing over the spot. The image of the central ray marker is then centred with the ring, appearing as a darker and smaller ring inside the image of the lead ring on the fluorescent screen.

Electrical Review, April 4, 1903.

NOTE 151 — ON MEASURING THE DISTANCE OF THE SOURCE OF X-LIGHT WITHOUT REMOVING THE EYES FROM THE CRYPTOSCOPE

It is often necessary in making a diagnosis with the cryptoscope to vary the distance of the source of X-light without removing the eyes from the image on the fluorescent screen, as, for example, to get a preliminary idea of how far below the surface a foreign body or aneurism is, and to know at any moment the distance of the source of X-light and how much it has been moved to allow the variation in the shadows to give us the information we desire.

If a physician is provided with a tube box mounted, as shown in the figures in these notes, with the central ray marker, distance and position finder[148] attached to the diaphragm plate and controlled as shown, this can be done by mounting a non-radiable scale along one edge of the fluorescent screen. It then is only necessary to move the screen until the image of the central ray marker comes into convenient relations with the scale. The diameter of the image on the screen of the distance finder shows at once the distance of the source of X-light -Note 143- and by noticing how fast this changes, as the source of X-light changes, observing at the same time the change in dimensions of the shadow of the object under investigation, the relative changes give information in regard to the distance below the surface at which the object is situated. The scale is best made of a strip of lead notched at intervals of ten millimetres, with smaller, or millimetre, divisions between.

Electrical Review, April 4, 1903.

NOTE 152—ON ALTERING THE QUALITY OF X-LIGHT WITHOUT REMOVING THE EYES FROM THE IMAGE ON THE FLUORESCENT SCREEN

This may be done by means of handles operating the spark-gaps in series with the tube -Note 112- or with a tube such as was shown in earlier papers, in which the Crookes potash regulator was placed in shunt circuit, and operated by heat produced by the same generator used to excite the tube; the amount of current passing through the regulator being adjusted by

[148] The name orienter was applied to these instruments.

the length of the spark-gap in the regulator circuit. The second is the form of regulation figured here. The novelty of the method consists in altering the spark-gap, and consequently the character of the light, when the tube is at the standard distance for fluoroscopic examinations, or beyond the reach of the unaided hand. Plate 102 A, Figure 5, Note 149, shows this clearly. A rack is attached to the tube box. This rack bears a wire which slips through a ring in the head of the wire of the spark-gap of the regulator. A pinion controlled by the handle at the left — RH 4 — operates the rack, thus changing the length of the spark-gap of the regulator circuit, altering the degree of the vacuum and consequently the character of the X-light until it is suited for the examination. No fluoroscopic diagnosis is satisfactory unless the quality of the X-light can be controlled without removing the eyes from the image on the fluorescent screen during the whole examination. It is on account of the imperative necessity for such control that so much has been said in these notes at different times on this subject. It would be pleasant to see fluoroscopic examinations receive the attention which their importance in diagnosis merits. — Electrical Review, April 4, 1903.

NOTE 153 — ON METHODS OF MOUNTING THE ROENTGEN PENETRATION GAUGE

All gauges in which metals in varying thickness are used to test the intensity of X-light are Roentgen's. This note is not intended, therefore, to describe a new gauge, but to show convenient methods of mounting an old one. In Note 144 a new form of cryptoscope was figured with the mirror inside. The penetration gauge acts as a cover for the mirror, Plate 104, Figure 1. By means of a milled head on the outside the gauge can be turned down between the eyes and the fluorescent screen, Plate 104, Figure 2. With this construction the gauge is acted on by the X-light, which has passed unchanged through the fluorescent screen; therefore a separate fluorescent screen is mounted on the gauge. Another construction is to mount the gauge on the outside of the cryptoscope with a hinge, enabling it to be turned back when not in use. Either method insures the gauge being at hand when wanted. As diffused light should always be excluded in all photometric work, the rod controlling the size of the opening in the diaphragm plate, Plates 101, 103, Figures 2, 5 A, Note 149, should be turned until the opening of the diaphragm is so small the penetration gauge more than covers the illuminated area of the fluorescent screen. Pure tin in sheets one one-hundredth of a millimetre in thickness makes a convenient gauge, which might be adopted as a standard, to enable observers to describe the penetrating power of the light used, for the benefit of others. — Electrical Review, April 4, 1903.

NOTE 155 — ON REFLECTING CRYPTOSCOPIC CAMERAS

The first reflecting cryptoscope and the first cryptoscopic camera were described and illustrated in the International Dental Journal for July, 1896, or almost seven years ago, yet these instruments are not in use by others. In Note 48 was described and illustrated a cryptoscope of this type which enabled the observer to see and hear the sounds of his heart and lungs. Since 1896, a number of types of reflecting cryptoscopes and cryptoscopic cameras have been made and found useful. Therefore one more attempt is made to attract attention to them. Two instruments of this type are illustrated in this note. They are intended to enable the observer to see the image on the screen when the source of light is above the patient, the photographic plate or the fluorescent screen being below. Ordinarily with the light in this position the image on the screen could not be seen, as the observer would not care to get under the table. The image on the screen ought to be seen to arrange the position, distance and direction of the light, and to find where the image of the orienter strikes the screen, that it may appear on the negative in proper relation to the image of those parts of the patient which are being photographed. Refer to axioms in Note 148. The image on the screen ought to be seen, while the photograph is being made, to know how long an exposure to give, and if the exposure is of some length, to keep the light properly adjusted to bring out details in the tissues. The first camera to be described was used in the method of anthropometrical signalment mentioned in Notes 147 and 147 B.

The person who is to be signalized is placed on the examination table shown in Plate 56, Figure 95, Note 116 B, March 9, 1901, and in the figures of Note 139. Instead of the plate-holder there illustrated, a reflecting cryptoscopic camera is used. The top of the camera -Plate 105, Figure 1- is made of a thin layer of the material known to electricians as fibre. The remainder of the camera is of wood, painted on the inside with white lead until the walls are non-radiable. There is a recess directly below the fibre top for the insertion of the plate-holder, while below is the fluorescent screen. By an arrangement of springs the fluorescent screen is pressed against the fibre top, but when the plate-holder is inserted, the screen is forced down until the plate-holder occupies the same position as that of the screen when the arrangements of the distance of the light were made -Plate 108, Figure 2-. The screen remains below the plate-holder, enabling the X-light which comes through to make an image on the screen. The springs also serve to press the plate-holder against the top. The eye-piece belongs with the cryptoscope shown in the figures in Note 145, and fits all the cryptoscopes and cameras. The observer -Plate 106, Figure 3- looks through this eye-piece to the mirror, where he sees the image of the feet on the screen, whether the plate-holder is in place or not. He therefore can adjust the light and the position of the feet before the photographic plate is put in the camera. In former notes it was shown the plate-holders should be constructed on a new plan, of non-radiable material, except in front, where the direct X-light entered. In using a reflecting cryptoscopic camera constructed of non-radiable material, the plate-holder does not require a non-radiable back, for that part is protected from the diffused X-light in the room by the walls of the camera. In a plate-holder for a cryptoscopic camera the back of the plate-holder should be made of radiable material to allow the X-light after passing through the plate-holder to strike the fluorescent screen to enable the observer to watch the object being photographed. Roentgen said zinc reflected X-light, therefore zinc backs were used in some of the plate-holders for reflecting cryptoscopic cameras; for while this metal is sufficiently radiable for the purpose, its reflecting property may shorten the exposure of the photographic plate. Plate-holders of this kind are not illustrated here, as they differ from the ones shown in earlier notes[149] only in the construction of the back, which may be of zinc or aluminum. It is evident with the form of camera here mentioned for use in photographing the feet, no plate-holder is required, as the plate, being protected by the fibre front of the camera, may be used in the ordinary paper envelope, but in the next form of the camera a plate-holder is desirable to allow the plate to be used either outside or inside of the body of the camera. In using the X-light for anthropometrical signalment[150] it is essential the source of X-light should occupy a constant position in regard to the part of the body to be photographed. In case of the feet, the central ray should strike the plate at a point between them and opposite the joints between the metacarpal bones of the great toes and the internal cuneiform bones. In signalitic measures of the feet by X-light, the source of X-light may be placed at a distance of seventy centimetres from the photographic plate with the distance finder at half this distance. With the

[149] Notes 121 and 140.

[150] Notes 147 and 147 B.

parts properly arranged, the image formed by the orienter will be a square of a diameter of eight centimetres with a circle in the centre. As the parts of the orienter -consult Note 137, March 29, 1902, and Notes 143, 148, 149, 150, and 151- are non-radiable, their images appear on the negative with the images of the bones. The negative therefore contains evidence of the position and distance of the source of X-light, as well as the angle at which the central ray struck the plate. The second camera -Plate 107, Figure 4- to be described has the same general construction. It is hung from the side rails of the examination table, along which it can be rolled to bring it under any part of the patient, who is in a horizontal position on the stretcher. For use it is brought into approximately the correct position. The observer then looks into the eye-piece, seeing on the mirror the image of the shadow of the patient's organs formed on the fluorescent screen. By means of the various handles -consult Notes 148, 149, 150, 151, and 156- connected with the tube box and stand, the light is brought into proper relations and made of the right quality. The photographic plate can then be inserted as in the first camera, or it may be placed on the top of the camera in contact with the stretcher, one end of which is lifted to permit of its insertion. A lifting mechanism for the stretcher has been figured in former notes. A better one is shown in Plates 105 and 108, Figures 5 and 6, here. Each end of the stretcher is held in bronze bars, one of which is shown, B. This bar is in two pieces, which can be separated by turning the milled head MH, Plate 108, Figure 6, which acts on the screw S, forcing the two pieces apart. This enables the canvas of the stretcher ST -Plate 105, Figure 5- to be made as taut as desired. To lift one end of the stretcher in order to place the patient at an angle with the horizontal, a wheel W is turned, bringing into action the compound screw QS, one end of which is permanently attached to the bronze bar B. This arrangement is practical and strong. The stretcher can be removed at any time by lifting it out of the notches in the bar. Further explanations of Plates 105 and 108, Figures 5 and 6: H, handles of stretcher; T, section of the end bar of the examination table, to which the nut N, of the screw QS, is attached; ST, steady pins; S, screw forcing the two pieces of bronze bar apart. Refer also to Plate 114, Figure 7, Note 156. Other forms of cameras in which a cryptoscope and camera are combined, intended to be used when the light is below instead of above a patient, will be described later. As they do not contain the reflecting principle, they do not properly come under the title of this note.

NOTE 156—ON SUPPORTS FOR X-LIGHT TUBES

It is obvious an X-light tube must have a support to enable its distance and direction from the patient to be varied. The commercial supports, being without exception constructed on incorrect principles, fail to meet the conditions of medical, medico-legal practice and those of anthropometrical signalment. A suitable tube-holder will therefore be described and illustrated, which is an improvement on those shown in earlier notes, though constructed on the same general plan to suit the conditions already several times, and now once more mentioned, for repetition is necessary until faulty methods are abandoned. The conditions to be met are: First, An X-light tube should be in a non-radiable box from which no X-light can escape except the smallest beam that will cover the area to be examined, photographed or treated. -First axiom, Note 148.- Example showing the importance of this, — the experiments reported in the Boston Medical and Surgical Journal in 1901 and 1902 proved X-light could burn, make blind and kill animals. Second, The box holding the tube should be attached to a strong upright column to allow the tube to be placed at any height above the floor up to the level of a tall man's head. For a tube is sometimes required to be placed under a patient on a couch, sometimes opposite the chest of a patient in a sitting posture, sometimes above a patient in a reclining position or on a level with his head while standing.

The weight of the tube box and attachments, about fourteen kilogrammes for the ones shown in these notes, should be counterbalanced by a lead weight inside the vertical column, that the tube box may be easily moved vertically and remain in any position without clamping. This adjustment must be capable of being made when the tube box is beyond the reach of the observer's arm, for when a tube is at a proper distance above, on a level with or below a patient, it is beyond the reach of the observer, yet, as stated in Axiom Third, Note 148, all adjustments for controlling the light require to be made under these circumstances. For the vertical movement, a handle H -Plate 109, Figure 1- projects to any distance required beyond the upright column VS. The distance of the handle from the upright column can be varied, as the rod S 2 slides freely in the square hole through the shaft B -Plate 110, Figure 2-. The handle H -Plates 109 and 110, Figures 1 and 2- can be placed at any height by means of the support SU, which bears the mechanism through which the vertical and horizontal motions are imparted to the source of X-light. Axiom Three showed all adjustments of the source of X-light must be capable of being made by the observer while looking in the cryptoscope. It is therefore obvious the position of the handle H must vary through a wide vertical and horizontal range, for sometimes it must be below the source of light and to one side of the examination table, as in Plate 106, Figure 3, Note 155, or below the source of light and the examination table, as in Plate 107, Figure 4, Note 155, or above the source of light, as in Plates 109 and 114, Figures 1 and 7. It is therefore important the support SU should be easily detached from the vertical support to enable its position to be quickly changed from above the vertical slide bearing the tube box to below it. Also it is necessary the means of clamping used should make the support very rigid, as it bears the mechanism through which motion is imparted to the source of light. Several forms of support were tried; the one illustrated was found efficient. Plate 110, Figure 2, shows the method of clamping to the vertical support VS. By means of the milled head MH acting on the screw S, the angle piece A is forced forward, pressing the vertical support SV into the angle C of the support SU. To remove the support, the screw is turned in the reverse direction. The dotted lines show how the support can then be freed. To make the vertical adjustment, the handle H -Plates 109 and 110, Figures 1 and 2- is turned, imparting motion through the shaft S 2 and the gear P to the rack R, one end of which has a socket BS -Plate 109, Figure 1- into which fits the wooden rod RWR which is clamped by the screw BSM. The rod RWR passes through a socket attached to the vertical sliding sleeve VSS, carrying the horizontal arm SA of the tube box TB. The wooden rod RWR can be clamped to the vertical sliding support of the horizontal arm at any distance from the support SU up to one hundred and eighty centimetres, which is a sufficient range. When clamped, turning the handle H raises or lowers the source of X-light. To make the movements easy, the weight of the tube box and arm is balanced by a lead weight inside the vertical column VS and SV -Plates 109 and 110, Figures 1 and 2-, and two rolls RO -Plate 109, Figure 1-, one at the top, the other at the bottom of the vertical sliding support VSS, reduce the friction. Fourth, The upright support VS should be securely attached to a firm base, which can be easily moved on the floor in any direction on castors -Plate 108, Figure 2, and Plate 107, Figure 4, Note 155-. Fifth, The tube box should be attached to the vertical sliding support VSS by a sliding arm SA, as already mentioned, and this arm should be graduated into centimetres on either side of a zero-mark o -Plate 109, Figure 1-; an index being provided, the point of which can be brought over the zero-mark, at whatever distance this may be from the vertical support VS. This horizontal adjustment should be capable of being made when the tube box is beyond the reach of the observer's hand. -Axiom Three, Note 148.- The swinging arm which Williams has substituted for the sliding arm is less desirable, for it does not lend itself to this procedure. Example showing the importance of this movement, — in examining a pelvis to determine the size of the brim, the tube requires to be moved through a measured distance to bring the source of X-light first directly under one side and then under the other to avoid distortion, for otherwise the width will be exaggerated. To get results quickly, means must be provided whereby the changes in the position of the source of X-light can be made without removing the eyes from the image on the fluorescent screen. The graduated arm taken in connection with the orienter and handles for controlling the movements of the tube enables this to be done. The distance through which the tube is moved can be found from the number of turns of the handle HH -Plates 109 and 110, Figures 1 and 2-, or it can be read from the graduations afterward. This handle HH is necessary in making all accurate transverse movements. Rough preliminary movements can be made by having a short track on the floor to engage the castors of the tube support. The castors can be quickly freed from the track when it is necessary to move the tube stand in other directions. Plate 109, Figure 1, shows the mechanism of the horizontal motion in detail. Motion of the source of light is imparted through the arm SA by turning the handle HH, which is always within reach of the observer, without removing the eyes from the image on the fluorescent screen. -Refer to Plates 106 and 107, Figures 3 and 4, Note 155.- The square wooden shaft SS operates the bevel gears GR 1 and GR. These turn the gears G 1 and G 2 by means of the square wooden rod VR. The gear G 2 operates the rack HR of the horizontal arm SA, to which the tube box TB is attached. The rod VR slides freely through a square hole in the shaft of the gear G 1, allowing the tube box to be raised or lowered without interfering with its horizontal motion. To allow this motion to be free, the arm SA moves on the rollers RO. The tube box should be arranged to turn through two vertical arcs whose planes are at right angles, the axis of one being parallel with the long axis, the other with the short axis of the X-light tube. Examples showing the importance of this, — Plates 78 and 79, Figures 4 and 5, Note 140; Plates 111 and 112, Figures 3 and 4, Note 156, where the tube is shown in position for treating diseases of the face and mouth. This movement in vertical arc is important when using the light concentrators illustrated in Note 144 and in the present note. Plates 85 and 86, Figures 9 and 10, Note 140; Plate 106, Figure 3, Note 155; Plate 114, Figure 7, Note 156, — show clearly the importance of having the tube box turn about an axis parallel to the transverse axis of the X-light tube. The best method is to use worm gears, for then the clamping device shown in the illustrations is not required, but as the mechanism is expensive, it is not shown. As the weight of the tube box and its support was increased, the clamping devices first shown were found inconvenient. A better method, illustrated in detail in Plate 113, Figures 5 and 6, was adopted. A steel rod with a milled head at each end for tightening serves as an axis on which the tube box turns. The arm BT ends in a circular piece into which a metal plate MP is set. The milled head MH is attached to a screw which turns in the nut N recessed in one of the projections, Plate 113, Figure 6 of the tube box. By turning the milled head, pressure is made upon the metal plate, thus securely clamping the arm in any position. This may seem too simple to need mention, but where a piece of mechanism is in daily use, ease and precision of working are important. Sixth, the tube box should have three rectangular openings, through any one of which X-light can escape for the examination of a patient above, in front, or below the source of X-light. Two of these openings should be closed with non-radiable slides, one of which should be transparent to allow the tube to be seen -Plate 107, Figure 4, Note 155; Plate 114, Figure 7, Note 156-. The third opening should be provided with a slide having a non-radiable diaphragm plate containing a rectangular opening whose size can be regulated, while looking at the patient in the cryptoscope, in order to reduce the illuminated area to the required extent, Axiom One, Note 148. This diaphragm plate has already been fully illustrated in Note 149. Other slides should be provided for the attachments of the light concentrators and light benders shown in Note 144, Note 156, Plates 111 and 112, Figures 3 and 4. All the slides must be interchangeable, that they may be placed at the top, in front, or at the bottom of the tube box. Plates 106 and 107, Figures 3 and 4, Note 155, show the tube box with the diaphragm plate and shutter arranged for a patient below the source of X-light. The orienter -Notes 119, 143, 148, 155, Plates 106 and 107, Figures 3 and 4; Note 156, Plates 109 and 114, Figures 1 and 7- must be mounted on the diaphragm plate, that their movements may be simultaneously controlled by the observer, who must be able while looking in the cryptoscope to regulate the area illuminated and bring the orienter into position to record automatically on the negative or screen the distance and direction of the source of X-light -Axiom Four-, the angle at which the central ray strikes the screen or plate -Axiom Five-, for all these must be clearly shown on the negative and be seen during the whole of an examination with a cryptoscope, if the work is to be done in a scientific way, for during an examination the amount of light, the relative position of the source of light, the patient, and the cryptoscope need frequent changes. These plans have never found their way into the standard works on X-light, where less perfect methods like plumb lines are described for adjusting the position of the light in relation to the patient, and where no means of making the necessary adjustments of the source of X-light during the examination are given. The average physician will always find fluoroscopic examinations so difficult he will need all the instrumental help he can get; therefore in these later notes, at the risk of repetition, apparatus is being described which was constructed for a friend for use in a small hospital, hoping in this way to meet some of the deficiencies of the text-books on the subject of proper apparatus for fluoroscopic and therapeutic work. When suitable apparatus is adopted, fluoroscopic examinations will become more rapid and more scientific, because more precise. Seventh, The tube box should be provided with an automatic shutter for instantaneous photography of the chest. A shutter was described and illustrated in Note 139. A better was incidentally shown in Notes 149, 155, 156. It will be described in detail later.

NOTE 157—ON THE MEANS OF ATTACHING THE TERMINALS OF THE X-LIGHT TUBE TO THE ELECTRIC GENERATOR

At first all X-light tubes were provided with platinum loops at the ends for the attachment of the wires from the generator, which were hooked into them. Finding an accidental pull on the wire -which was quite likely to happen in the darkened room where all fluoroscopic examinations were made- cracked the tube about the wires, thus spoiling it until repumped, loops were abandoned for a spiral spring contact, the terminals of the tube being straight projections -Note 4, December 15, 1897, and Note 138-. The spiral spring arrangement was illustrated in Note 139. A better form, because easier to operate in a darkened room, is illustrated here. In Note 36, Plate 12, Figure 34, was shown a non-radiable tube box with sliding arms, which had been used since 1896 to prevent any X-light from escaping into the room except what was required. It is to a box of this kind, — indicated by the letters TB, Plate 115, Figures 1 and 2, — the sliding arm A supporting the contact-post CP is attached, that the contact-disk D may be brought against the terminal of either a long or a short X-light tube. The arm is clamped in any position by the milled head MH. The contact-disk D is attached to the end of a steel rod R, around which is a spiral spring of piano wire SP, which always keeps the contact-disk pressed against the terminal wire of the X-light tube T. The contact-post is insulated by the hard rubber collar and sleeve HR. The length of the contact-post can be varied. It is held in any position by the screw S. Another similar screw clamps the wire W from the electric generator to the contact-post. The means of attachment shown in Plate 115, Figures 1 and 2, are safe and rapid. However hard an accidental pull is given to the wires from the generator, no strain is brought upon the X-light tube, and, moreover, as there is always contact between the terminals of the tube and the electric generator, there is no spark-gap where they join, and consequently no heat from this source to crack the tube around the terminal wire.

Electrical Review, June 6, 1903.

NOTE 158 — ON METAL TUBES BETWEEN THE X-LIGHT TUBE AND THE PATIENT FOR IMPROVING THE DEFINITION OF THE PHOTOGRAPH

In 1896 Leeds and Stokes published photographs showing a diaphragm improved the sharpness of an X-light photograph. In August of that year was printed in the International Dental Journal a description and illustration of an improvement which made a diaphragm of more use in medicine. The diaphragm was not fixed, but could be quickly made concentric with the central ray of X-light used to take the photograph. This was important, for the central ray should always strike the plate normal to its surface. Later it was shown no X-light should be allowed to strike the patient except enough direct X-light to cover the area to be examined, treated or photographed. A tube box which made the procedure practical was illustrated. It was also stated -Note 10, January 5, 1898- that the light should be of such wave-length as suffered least diffusion in the tissues, and it was proved that scattered light which resulted from using X-light of improper wave-length prevented sharp images, because it suffered unnecessary diffusion in the tissues. This note and Note 6, December 22, 1897, on the same subject, were important contributions to X-light literature, though their value is not yet clearly recognized. Another reason given for preventing the escape of all unnecessary X-light was this, — as X-light spread as a spherical wave, filling a room with an actinic mist which radiated X-light in every direction, penetrating through the back of the plate with sufficient force to make images of objects on the opposite side from the source of light, it was essential to prevent the escape of every ray not needed to make the photograph or to illuminate the screen. Several physicians have since described apparatus which embody some of these ideas imperfectly. One case occurs in a recent German work, brought to my attention to-day by a friend who partly translated it to me. In this book are many illustrations of the author's methods of improving the definition of the image on the photographic plate. In America physicians look to Germany for guidance. Any German medical apparatus will receive attention though earlier and better apparatus of American design had previously been ignored. Therefore some errors of the author are mentioned. Instead of covering the patient with a non-radiable sheet to exclude all diffused X-light, as recommended[151] in earlier notes, placing the tube in a non-radiable box from which no X-light can escape except the smallest beam that will cover the required area to be examined, treated or photographed -the tube box being mounted on an independent support that the patient may easily be moved into proper relation to the source of X-light-, the author attaches the tube to the examination table on which the patient is lying. Between the X-light tube and the patient he places a metal cylinder extending to the body of the patient. The sides and back of the X-light tube are open for the escape of X-light, thus allowing the room to be filled with actinic mist with the consequences already mentioned. This arrangement allows much more X-light to strike the patient than is useful, for X-light spreads as a spherical wave from the radiant area on the target. The unnecessary X-light strikes the sides of the metal cylinder. Roentgen and Tesla have shown metals reflect X-light as chalk does light of longer waves. Other observers have proved every metal surface on

[151] Note 94.

which X-light strikes becomes a source of light having some similar properties. It is evident, therefore, the use of a metal tube introduces elements of fog to the photographic plate, because the extra reflected and transformed light suffers diffusion in the tissues -Note 10-, blurring the image on the plate; for it is not of the right kind and is not direct light arising from a small point, but from a very wide area, and therefore incapable of making sharp shadows. To get the exceedingly sharp images of objects which X-light, when scientifically used, can give, we must exclude as far as possible all X-light except what arises from the small radiant area of the target -consult Notes 41 and 41 A, where a figure of a tube having an internal diaphragm was shown-. This important principle is an X-light axiom, and may be stated in the following words. Axiom Sixth, In making photographs by X-light, only the beam arising from the radiant area on the target should be allowed to strike the photographic plate. Projecting metal tubes such as have been criticised were made in the summer of 1896, when less was known, but the plan of having the interior surfaces of metal was abandoned except for therapeutic purposes. For this work cones were later used -consult Note 144, Note 156, Plates 111 and 112, Figures 3 and 4- instead of cylinders, thereby turning a defect into a benefit, because the reflected X-light was useful, increasing the intensity of the illumination. Moreover, it allowed the light to be turned around a corner, a feature of importance in treating diseases of the mouth and other cavities and affections of the prostate and other glands near the surface, where it was not easy to use the direct beam on account of inconvenience to the patient. If one wishes to use tubes between the X-light tube and the patient in photographic work, they should be made of fibre or wood or some similar material and painted on the inside with white lead to make them non-radiable. The proper place to attach such tubes is not to the examination table on which the patient is placed, but to non-radiable tube boxes from which no X-light can escape except through the metal tube -Plates 111 and 112, Figures 3 and 4, Note 156-. The X-light tube and its box should always be on an independent support, that any part of the patient may be quickly brought into proper relations to the source of light. All methods of attaching the tube to the support on which the patient is placed are unwise except in certain special cases like those developed by Moritz for drawing the outlines of the internal organs. The cross-section of the metal tubes criticised is a circle. Therefore, either some of the photographic plate will be wasted or the tissues will be illuminated unnecessarily. Consult here Note 149, Plate 116, Figure 1. If such cylinders are used for fluoroscopic work, the cryptoscope must be larger than needed or else there will be unnecessary illumination of the tissues. Size is of importance with properly constructed cryptoscopes, which are heavy when they are non-radiable, as they should be. The author might escape these difficulties by using round plates and cryptoscopes, but this does not seem very practical at present for photographic plates, though for cryptoscopes the construction is not objectionable for some work, and for special cases such round cryptoscopes have been used, in the smaller seehear, for example. If metal tubes are used between the X-light tube and the patient, the cross-section may therefore well be rectangular as in the figures of the concentrating pyramids already illustrated. In regard to the supports for such tubes, the arrangement in which the tube is mounted on an independent support, the patient on a freely movable table for horizontal positions, or on a similarly freely movable platform for standing or sitting positions, is recommended as most practical, for it admits of rapid adjustment. — Electrical Review, June 6, 1903.

NOTE 159 — A BREAK NOT A NECESSARY PART OF AN INDUCTION COIL

It is frequently said in comparing static machines with coils for exciting X-light tubes that the necessary defect of the coil is the break, which makes the light too unsteady for use with the fluoroscope. Those who make this criticism forget a break is not an essential part of an induction coil. One reason why in these notes coils of high potential have been recommended for exciting X-light tubes was, such coils did not need a break, for by using an alternating current from a commercial alternator in the primary it was practical to develop sufficient potential in the secondary to excite an X-light tube, even though it had a low resistance. Spottiswoode and Ward were the first to prove a coil could be operated in this way for vacuum tube work. In 1879 they showed a twenty-inch coil could be employed with an alternating current from a De Meritens dynamo in the primary. The spark from the secondary was seven inches long,[152] the size of a cedar lead pencil, extremely steady and suitable for spectrum work without a condenser in the secondary. The type of coil described in Notes 112 and 137 is suitable for these heavy discharges, as there is no danger of burning out the secondary.

Electrical Review, June 27, 1903.

NOTE 160—SMALL OR LARGE INDUCTION COILS FOR EXCITING X-LIGHT TUBES

It is commonly stated that large coils are not required for exciting X-light tubes because the resistance of a tube for medical work never requires it to be over three inches. Therefore to use a coil giving a higher potential than necessary to overcome this resistance is unwise, for large coils are expensive, cumbersome, and do not give a sufficient volume of current, owing to the length of fine wire in the secondary. It is well, however, to have a good memory for the work of the great experimenters. For example, Trowbridge took a photograph of the bones of the hand in a millionth of a second with a generator having sufficient potential to send the discharge across six feet of air. Until those who are advocating coils having a potential only sufficient to excite a tube of moderate resistance can make as short exposures, their arguments against high potentials are weak. At present they are giving exposures from thirty to sixty million times that mentioned. As the use of small coils is still advocated, it may be worth while to repeat some of the reasons given in

[152] With the more rapid alternations from special dynamos longer sparks may be obtained.

earlier notes for the use of high potentials with X-light tubes. First, when a tube is pumped for X-light work as much gas should be left in the terminals as practical, that the life of the tube may be long. Such a tube can be used some hours before it requires to have the resistance lowered by introducing fresh gas from a regulator. When a powerful discharge is first sent through the tube for more than a few minutes at a time, so much gas is liberated the resistance becomes less than one millimetre. Under these circumstances, with a coil of low potential no useful X-light can be obtained. If, however, the coil has a high potential, by holding back the surges the sub-atoms in the cathode stream strike the target with sufficient force to get heated enough to produce X-light of proper quality for medical work, notwithstanding the increased cloud of particles in the tube through which they must make their way. This is one reason why high-potential coils are useful for the present. Second, Such a tube has a far longer life than one in which the terminals have been made very dry to prevent a powerful current from lowering the resistance rapidly. Third, In attempting to use an alternating current in the primary of a small coil, in order to get a steady light by discarding the break, as mentioned in Note 159, the coil has a less potential, and is therefore less fitted for the work. Small coils are most suitable for portable apparatus, and when used the tubes should be provided with automatic regulators of the type shown in Note 138, the terminals being left rather dry that the large volume of current may not lower the resistance more rapidly than can be compensated by the reabsorption of the gas first liberated from the regulator to lower the initial high resistance sufficiently to enable the current to pass. Where two theories are held, the best way to decide which to follow is to push each to the extreme. When the theory of high potentials for exciting X-light tubes is pushed to the extreme, we get Trowbridge's result of a very short exposure. When we follow a similar course with the other theory of low potentials, it is impossible to get an X-light photograph, no matter how long the exposure, for the sub-atoms in the cathode stream are not driven against the target with sufficient force to produce X-light. In connection with low potentials for use in the future, when X-light tubes shall have been perfected, it is well to remember the two following experiments by distinguished men, for they are significant, as they show coils or static machines form no necessary part of an X-light apparatus. In 1897 Dr. Williams told me he had seen Professor E. Thomson produce an abundance of X-light with one of my cooled target tubes from a dynamo. About 1900 Professor Trowbridge showed me an X-light tube brilliantly lighted by a battery current. Probably in neither case was the voltage over twenty thousand. This could be yielded by a coil giving a spark not over two centimetres. It is evident, then, a current of low voltage, easily obtained without a coil or a static machine, can produce brilliant X-light of suitable quality for medical work, provided the tubes are in proper condition. At present a difficulty is that tubes do not remain in suitable condition for the use of large currents when their potential is low. — Electrical Review, June 27, 1903.

NOTE 161 — ON MOVING THE PLATINUM TERMINAL OF AN ELECTROLYTIC BREAK

Soon after the German rediscovery of the Spottiswoode or electrolytic break was described in the Electrical Review, it was experimented with for interrupting the current in the primary of an induction coil used to excite an X-light tube. The light was not steady enough for diagnosis with the fluorescent screen. During attempts to make it steady the platinum point was moved in the solution to free it from gas. The idea was explained to Mr. Heinze, who afterward utilized it in a very ingenious break. Some of the methods used during these experiments for moving the electrode were mentioned in earlier notes, and now another made at that time is illustrated. The platinum point was in the form of a screw which was revolved by a small motor. The depth of immersion was varied by a screw operated by the handle RH 5, having a spiral spring like those described in earlier notes. In this way the operator could control the intensity of the X-light during an examination without removing his eyes from the image on the fluorescent screen. The figure will make the construction of the break clear.

Electrical Review, June 27, 1903.

NOTE 161 B — ETHER THERAPEUTICS WITH THE NERNST LAMP

Ether waves from two forms of electric lamps are now used extensively in therapeutics in Europe and to a less extent in America. Where short ether waves are required, the arc is the more suitable, as the temperature is higher, making the proportion of short waves greater; and having no glass covering like the incandescent lamp, there is no absorption from this source. Glass absorbs practically all the waves shorter than three thousand, as does the atmosphere those given out by the sun. During the past year experiments have been made with Professor Walter Nernst's lamp, in which a rod containing a preparation of zirconia is heated by an electric current. This, like the arc, requires no glass covering, though it is supplied with one. Loss of short waves is therefore avoided. The light is well suited for use in therapeutic cabinets in which an even distribution of radiant energy is desired and obtained by using many incandescent bulbs, — over ninety in one of Dr. Kellogg's. A second advantage over incandescent bulbs is that the consumption of current for the same number of light waves is greater, less of the current being converted into the longer heat waves. The Nernst lamp will not supersede the older forms for therapeutic purposes, but it is certain to have a place of its own. Ether waves are now so much used in medicine it seems desirable to have some general term under which all the forms, such as X-light, ultra-violet light, actinic light, ordinary white light, red light, heat and electric waves, can be grouped. I am in the habit of using the term "ether therapeutics" for this purpose, and suggest it to others as a broad and definite term.

Boston Medical and Surgical Journal, July 9, 1903.

NOTE 162 — A WAGON FOR X-LIGHT EXAMINATIONS

The term wagon is used to emphasize the fact that the support for the patient is on wheels. In

Note 116 B, March 9, 1901, the importance of this plan in X-light examinations was mentioned and the reason given why it was superior to the universally employed method of a fixed support. The plan of mounting a patient on an axis that he may be turned in a horizontal plane and providing a graduated circle for indicating the amount of rotation is not claimed as original. It has been used by Williams for examining a patient in a sitting position in an office chair, elevating with a screw. For examining a patient's chest from the front, the standing position is better, as the patient's knees and the arms of the chair make the sitting position inconvenient to the physician, therefore the X-light wagon here described is arranged not only for a sitting but also for a standing position. The wagon is furnished with a turn-table -TT, Plate 117, Figure 1- which has the usual graduations, and is provided with a stop S, holding it in any position when a photograph is being made. The base of the wagon and the turn-table are made of hard wood, cross-glued in three layers. There are four wheels, each thirty-six centimetres in diameter. The wheels may be deemed larger than necessary. The size was chosen to enable the movements of the wagon to be easily made by one hand during an examination, that the relative positions of the source of light and the patient might readily be changed without removing the eyes from the image on the screen. To the wagon base three upright metal sockets are attached. Two of these, US 1 and US 2, hold two metal tubes, HU 1 and HU 2, which support the frame OF, holding the inner frame PHF, Plate 120, Figure 2, for the plate-holder and fluorescent screen. The frame OF can be turned about a horizontal axis to enable the fluorescent screen or photographic plate to be tilted from a vertical position when necessary to bring either closely against the patient. Usually in examining the chest from the front, the top of the fluorescent screen needs to be tilted back, as shown in Plate 117, Figure 1, and Plate 118, Figure 1 A. The frame can be swung to one side by sliding back the socket SI, or removed by also sliding back a similar socket on the other side. The supports, SS 1 and a similar one on the other side, slide on the uprights to enable the frame to be adjusted to any height, where it will remain without clamping, as it is balanced by weights within the uprights. Clamping screws are provided for preventing movement during photographic exposures. A back support for the patient can be attached to the extra sockets, ES and a similar one on the other side. The frame OF is provided with a non-radiable pyramidal case NRC,[153] which has the same non-radiable eye-piece shown in earlier notes. For examinations with the screen this case is convenient, as the room need not then be very dark. For photography it has the advantages mentioned in Note 155. In making tracings of the organs, the case NRC may be entirely removed, as in Plate 118, Figure 1 A, the room being dark, or an opening may be made in the side and provided with a sleeve for the insertion of the hand

[153] It is better to attach the hood NRC to the frame PHF, instead of to the frame OF, for the milled head is then outside. The hood NRC should then be made of non-radiable metal like the other cryptoscopes shown in Note 145.

bearing the tracing pencil. If the screen is used without the case, it must be covered by a plate of heavy lead glass to prevent the X-light from injuring the eyes of the observer. This protection of the eyes is a point which is neglected. It is frequently mentioned, as the experiments on animals showed the light could produce blindness. Over the glass is placed the tracing paper or cloth in the usual manner. The glass and the tracing paper are held in a frame, shown in detail in Plate 119, Figure 3. To compare one tracing with another, we have only to see that the image of the orienter occupies the same position on the screen in every case and that a tracing of its image on the screen is made on the paper when the shadows of the organs are sketched. To maintain a definite relation of the tracing paper to the patient, I designed for Dr. Williams a frame PHF, shown in detail in Plate 120, Figure 2. It is of metal of proper size to receive either or both the fluorescent screen and plate-holder, or the fluorescent screen and the glass plate, either with or without the tracing cloth. There is a boss B, of polished metal which fits into the sternal notch of the patient, a definite and easily distinguished point in the anatomy which is therefore satisfactory as a base station. The boss is hollow, containing a spring-actuated needle PN, which pricks a hole in the tracing paper, thereby indicating on the tracing the position of the base station, from which all measures of the tracing should be made when comparisons are to be made. To insure that the tracing paper always occupies the same position in relation to the patient at every examination, it is also necessary to have some other reference points which may form a triangle with the base station. The idea of using the nipples for reference points as is done in percussion may be definite enough for so inaccurate a method, but it was discarded when Williams proved by X-light one could not determine accurately the outlines of an enlarged heart by percussion. The distance between the nipples in a woman of normal form varies several centimetres, according to the position of the body. In X-light examinations we expect the lines obtained by tracing to be capable of comparison within three millimetres. What was needed was some convenient method of indicating on the tracing paper the position of the medial line of the body, as this should be the line from which all transverse measures are taken, all vertical measures being referred to the pin-prick showing the position of the sternal notch. But how was the medial line to be accurately determined? The method shown in Plates 117 and 120, Figures 1 and 2, was found accurate. There are two arms, A 1 and A 2, attached to racks, R 1 and R 2, which are moved simultaneously in opposite directions equal amounts by turning the milled head TH, which therefore serves to bring the arms in contact with the sides of the patient's chest. If now a medial line is printed on the sheets of tracing paper, this line must indicate the medial line of the body when the tracing paper is in the frame PHF, provided the boss B is in the sternai notch. If this procedure is followed, a tracing made at one time can be compared with those taken at other times. The needle point already mentioned, which pricks the paper to record the position of the sternal notch, would prevent the insertion of the plate-holder into the frame if it was fixed, but it is forced back by the plate-holder into the boss B springing forward when the plate-holder is removed. If we do not wish to examine the image on the fluorescent screen while the photograph is being made, it is best to use the non-radiable plate-holders described in Notes 116 C, March 9, 1901, and 140, June 21, 1902. Under these circumstances the pyramidal hood NRC, Plate 117, Figure 1, can be turned back or removed, as the non-radiable back of the plate-holder protects the plate from the diffused and transformed light. If, on the contrary, we wish to see the organs while the exposure is being made, the back of the plate-holder should be of radiable material, the fluorescent screen being placed between it and the observer, stray light being prevented from reaching the plate by the hood NRC, which is closed over the plate-holder, the observer looking into the eye-piece EP, to see the image on the screen.

The projection of the images of the organs on a flat surface distorts them, and observers have recommended making the tracings on the skin and transferring the lines to the tracing paper, which is made to conform to the surface of the skin. This method is not practical with a woman of normal shape, as the breasts prevent it being accurate. As there is a necessary distortion if the source of light is stationary, the slight increase produced by the method recommended is not of serious importance; as for each patient the amount is fixed and therefore introduces no element of confusion. If we wish to avoid all distortion we must have the screen and tube move simultaneously, as has been done by Moritz. The future alone will determine which method is of most use. If we do not use the fluorescent screen in the non-radiable cone provided with a non-radiable transparent eye-piece, we should cover it with a sheet of heavy glass -which will also serve as a support for the tracing paper- to protect the observer's eyes from the X-light. The arrangement is shown in Plate 119, Figure 3. Whether the observer uses the direct vision cryptoscopic camera, NRC—OF, Plate 117, Figure 1, or the glass-covered open fluorescent screen, Plate 118, Figure 1 A, he has within reach six handles which allow him, in connection with the rolling motion of the X-light wagon, to make the necessary adjustments in the position and quality of the X-light, and by means of the break shown in the illustrations to Note 139 he can control the quantity. H raises or lowers the source of X-light. HH moves it toward or away from the patient. RH regulates the size of the area illuminated. RH 2 and RH 3 centre the opening of the diaphragm and the orienter with the central ray. RH 4 controls the quality of the light. In addition to the use of an X-light wagon for examining the head, neck, shoulder or chest of a patient in a sitting or standing position, it is useful for photographing the hand, forearm, elbow and upper arm. For these purposes it is provided with a reflecting cryptoscopic camera, similar to those illustrated in Note 155. This camera can be placed at different heights above the floor of the wagon. For photographing the hands for anthropometrical signalment by X-light, the turn-table, TT, Plate 117, Figure 1, is removed. The person to be signalized is seated on a stool with the camera in front -Plate 121, Figure 6-, the hands, palms down, resting on the top. The light is adjusted until the image of the central tube of the orienter is seen on the screen within the camera between the thumbs, opposite the first joints. In taking the forearm, wrist, elbow or upper arm the patient should be at the side of the camera which is brought to the proper level. Directions for the use of a camera of this type are given in Note 155. In examining the chest from the side, the cross-bar CB, Plate 117, Figure 1, which holds the uprights parallel, also serves as a support for the patient's hands, thus bringing his arm out of the field, which is necessary in studying the heart, as Williams' triangle, thus brought to view, is of an important diagnostic point. The frame OF, with all it contains, can be removed from the X-light wagon and attached to the examination table, as shown in Plate 122, Figure 8. The mechanism for this purpose is a modification of that illustrated in Note 139 for supporting a plate-holder with a non-radiable back. It is shown in Plate 120, Figure 5. VS is a piece of the side rail of the examination table. The milled head MH presses the rail into the corner of the clamp C, holding it securely, yet permitting of immediate removal when desired. A similar milled head also clamps the vertical arm PVR, and this in turn carries another arm 2 PVR, holding the frame OF, which can be turned about a horizontal axis to allow the screen or plate-holder to rest against the patient's chest. Thus tracings or photographs can be made with the patient in a horizontal position, the patient being relieved of all unnecessary weight, as this is supported by the rail of the examination table. Full details of the various positions in which this type of mechanism permits a plate-holder to be held were given in the note mentioned.

Electrical Review, July 18, 1903.

NOTE 163 — PULSATING CURRENTS FOR USE IN THE PRIMARY OF AN INDUCTION COIL

The advocates of static machines for producing X-light claim coils are unsuitable because the X-light cannot be made steady on account of the break, which they state is a necessary part of an induction coil. In earlier notes it was shown a break was not a necessary part of an induction coil. The current for the primary might be taken directly from an alternating-current dynamo. When a coil is excited in this way the double-focus tube may be used. Here an attempt will be made to correct the common error of ascribing the invention of the double-focus tube to other than Roentgen. The following quotation is from his memoir dated March 9, 1896: "A discharge apparatus was prepared especially for experiments with alternating currents of the Tesla transformer; in which both electrodes were aluminum concave mirrors, whose axes were at right angles; at their common centre of curvature there was placed a platinum plate to receive the cathode rays." Another quotation from the same memoir shows the statement that Roentgen was the first to employ the Crookes or single-focus tube was correct, notwithstanding it has been ignored by even the most recent writers, who credit the application to others. This is the passage: "I have for weeks used with great success a discharge apparatus in which the cathode is a concave mirror of aluminum, and the anode a plate of platinum placed at the centre of curvature of the mirror and inclined to the axis of the mirror at an angle of forty-five degrees." Both these quotations are taken from a work by Professor Barker, entitled Roentgen Rays, in which the original memoirs are translated into English and are therefore readily consulted. It will be observed in both types of tube Roentgen made the error of supposing with Crookes that the focus of the cathode stream was at the centre of curvature of the cathode. The fallacy of this was pointed out in Notes 2 and 3, and experiments mentioned which showed the focus was beyond. The matter is mentioned again because writers continue to state that the cathode stream particles move in straight lines, though experiments already mentioned have shown this to be incorrect as a generalization. Though an alternating current can be used in an induction coil without a break, thereby doing away with this source of irregularity in the X-light, it is customary when employing alternating currents in the usual way with a break to use a double-focus tube. A double-focus tube is not economical; the target is not an anode, and therefore the impact of the cathode stream sub-atoms is less efficient in producing X-light for reasons already given in detail; and also the life of these tubes is shorter, for the gases are more rapidly removed from the terminals. On these and other accounts attention is called to the plan of operating an induction coil by a direct pulsating current, in which the waves succeed each other fifteen or twenty thousand times a minute,[154] using this current in a properly shaped single-focus tube, and employing, as in the case of the alternating current under the same conditions, a large coil constructed on the plan described in Notes 112 and 137, in which the sections of the secondary are interchangeable. — Electrical Review, July 25, 1903.

NOTE 164 — ON THE RECOMBINATION OF THE CATHODE STREAM PARTICLES

In former notes experiments were mentioned which proved the kind of cathode stream used to produce a practical amount of X-light was made of sub-atoms and not of the ultimate particles of either electricity or matter. Not of electricity, for no cathode stream was formed when by heat and heavy surges the gases had been sufficiently removed from the terminals and pumped out of the tube, though the terminals were connected with a powerful source of electricity which on the electron theory should have furnished an abundant cathode stream and much X-light. Not of the ultimate particles of matter, for they gave a familiar spectrum, and ultimate particles must give a new spectrum if we ever get to them. It was also shown these sub-atoms must recombine, as the gas formed by the recombination of the cathode stream particles could be collected by a special arrangement of the pump, and by introducing it

[154] With more rapid pulsations from special dynamos smaller coils may be used.

into a spectrum tube[155] a spectrum could be obtained usually attributed to hydrogen, but since stated by Trowbridge to be that of water vapor. These old experiments are mentioned again because they are too interesting in connection with recent work on radio-active substances to be lost sight of. — Electrical Review, July 25, 1903.

NOTE 165 — ON THE BEARING OF THE VARYING FOCUS OF THE CATHODE STREAM ON THE ELECTRON THEORY

Those who hold the electron theory of the cathode stream claim it is composed of the natural units of electricity, each of which is like every other. Already in these notes reasons have been given for not accepting this view of the kind of cathode stream used practically for the production of X-light, but there is another point which may possibly be interesting. In Notes 2 and 3 it was said the focus of the cathode stream varied with the electric charge on the sub-atoms composing it. If the cathode stream was composed of electrons, that is, of particles of electricity free from "matter" and all having the same unvarying properties, the focus of the cathode stream should not vary in such a marked degree, for the greater or less repulsion between the sub-atoms due to the varying proportion of electric charge to mass -which is a cause of the variation in the distance of the focus from the cathode- could not exist owing to the sameness of the electrons. In this note the effect of the residual gases are not considered,

[155] The spectrum is best studied in the X-light tube by making the target to drop out of the path.

for the relations claimed by the advocates of the electron theory of the cathode stream make this legitimate. — Electrical Review, July 25, 1903.

NOTE 166 — ON THE TYRANNY OF OLD IDEAS AS ILLUSTRATED BY THE X-LIGHT TUBES USED IN THERAPEUTICS

Within two months two valuable text-books on X-light have been published in America. Each treats extensively of the use of X-light as a remedial agent. This proves the interest taken in this department of what should be called ether therapeutics. An examination of these works showed every tube illustrated for therapeutic work had a concave cathode. Now Roentgen first applied the concave cathode of Crookes to an X-light tube for the purpose of reducing the impact area of the cathode stream in order to have the X-light arise from a small surface to insure sharp definition. When X-light is used in therapeutics sharp definition is not important, therefore for some years I have rarely used an X-light tube with a concave cathode in the cavities of the body, — the mouth, for example. When a concave cathode has been used it has been for the opposite reason; namely, to spread, not to contract, the cathode stream. A concave cathode is of no value in most types of tubes for use in body cavities. It is a serious disadvantage when used in the regular way to bring the cathode stream to a focus, for it is frequently desirable to have the impact of the cathode stream against the glass wall of the X-light tube which is quickly melted by a powerful current when not cooled, or cracked when cooled. It is manifest the risk is diminished when the impact area on the glass is made larger, for the energy of the cathode stream, which is degraded into heat waves, is more widely distributed; the glass, therefore, does not get so hot and may be cooled with less risk.

Many forms of these flat cathode tubes have been devised; in all applying the principle first used in 1896, in tubes designed and constructed for Dr. Williams, — that of cooling the surface struck by the cathode stream. In earlier notes several forms of these cooled tubes were illustrated. The one in which an internal anode was cooled is now a common article of commerce. The second form in which an external anode was cooled is less frequently seen. It was first applied to a modification of Tesla's direct-acting X-light tube, which at that time greatly interested me on account of its symmetry. This method of cooling is of value in therapeutic work with tubes intended to be inserted into body cavities. For these purposes it is well to have the general form of the tube that of a cylinder of such diameter as will easily enter the cavity and to use a modification of a device first applied to X-light tubes by Edison -at least he used it as early as April, 1896-, that of external electrodes. Edison found a tube having internal electrodes, if exhausted until no current could pass, would become active if the ends were covered with tin-foil. The reason for this has not been given, but it is a very simple one. When the exterior of a part of the tube is covered by metal, the portion of the glass under it forms a terminal, and gas is driven from it, as it has been shown it is from internal terminals. Cylindrical tubes were designed with flat cathodes, in which the impact of the cathode stream was received on the glass wall of the tube, at the end opposite the cathode; the glass being covered at that place with thin aluminum-foil to act as an anode and yet permit the X-light to go forward without much absorption. In this tube the light not only goes forward, but spreads as spherical waves in all directions from every part of the glass struck by a cathode stream particle. When it is desired to limit the area illuminated or to send the beam in any given direction, the diaphragm illustrated in the International Dental Journal for July, 1896 -and in connection with direct-acting tubes, in the Electrical Review for 1898-, should be used in the form of a non-radiable tube enclosing the end of the X-light tube, which is inserted into the body cavity — the opening through which the light is to escape being closed by a radiable window -such as has been already illustrated in connection with a Tesla direct-acting tube-— to allow the water to circulate without escaping. The non-radiable sheath opposite the radiable window should be lined with a metal which reflects X-light. In other forms a convex cathode was used to spread the cathode stream, that it might strike the walls of the tube over a considerable area and thus make the source of X-light a long cylinder, the whole of the part of the tube inserted into the body cavity, for example, if desired; for X-light arises wherever the cathode stream particles strike with force. The same non-radiable sheath and zinc reflector are applicable to this form of tube, when it is desired to direct the light to one side of the body cavity. In other cases a concave cathode was used to spread and not to concentrate the cathode stream, thus causing the X-light to arise from a large area, as with a convex cathode. It is mentioned chiefly to show this is the way the therapeutic tubes with concave cathodes of short curvature work; though such was not the intention of the inventors, as may be seen by examining the illustrations published of these tubes. When a cathode of short focus is placed in a long tube, the cathode stream is brought to a focus in the tube near the cathode, but far from the tube walls. Therefore the stream spreads again, there being nothing for it to strike, and its impact is diffused over the inside of the tube, and from this large area the X-light arises instead of from the end of the tube where it is supposed to arise. This should be kept in mind in designing such tubes. Illustrations of flat and convex target tubes are not shown, for these should be made for the cases in which they are to be employed. It is desired only to point out the principles to be followed. Physicians who wish to use ether waves and electrons in therapeutics need special training quite as much as surgeons and other specialists, and should have inventive and engineering faculties to enable them to design and construct their own apparatus, that progress may be rapid and their patients well served. Speaking of electrons reminds me that the subject of burns from X-light apparatus is not yet clear in the minds of some recent writers, therefore it is again stated there are two sources of burns from such apparatus. In earlier notes it was proved a burn could be produced from an X-light tube in which the resistance was so high no X-light was being generated. This form of burn is due to electrons and can be made by radium.[156]

Electrical Review, July 25, 1903.

NOTE 167 — ON LARGE INSTEAD OF SMALL RADIANT AREAS IN X-LIGHT TUBES EMPLOYED IN THERAPEUTICS

In Note 166 a new principle in the therapeutic application of X-light was stated; namely, the use of tubes with diffused sources of X-light. A diffused source of X-light was obtained by making the cathode stream spread, instead of bringing it to a focus, as in all tubes previously used in therapeutics. Consequently the sub-atoms of the cathode stream struck the glass walls of the tube over a large area. As X-light arose wherever the cathode stream particles struck with force, the source of X-light was a large surface instead of a spot about two millimetres in diameter, as in focus tubes. In the present note the importance of this principle in ether therapeutics will be shown. In earlier papers[157] the principle to be followed in using X-light in therapeutics was stated; namely, when we wish to affect the superficial tissues most strongly we should use X-light from a tube of low resistance, because the X-light from such a tube is most absorbed by the tissues, placing the source of X-light near the surface to be treated. For treating deeper tissues we should use the X-light from a tube of higher resistance, because this form of X-light is less absorbed by the superfi-

[156] Refer to earlier notes for the therapeutic uses of radium.

[157] Boston Medical and Surgical Journal, April 24, 1902, and reprinted as Note 138 A.

cial tissues, placing the source of X-light so far away the intensity of the radiation where it enters the body shall not be measurably stronger than when it has reached the deeper tissues we desire to treat. These principles have now been accepted by a number of physicians who are using X-light in therapeutics. They are mentioned again to make clear the ideas on which the tubes to be described were designed. One other statement made in the paper mentioned needs to be considered.

It was shown that within the limits of the experiments the action of the X-light on the tissues diminished like the photographic intensity as the square of the distance. Beforehand this would have been expected, but it could not have been accepted as a guide in therapeutics until tested on animals. Therefore the experiments reported were made, furnishing a safe rule to follow in using X-light in therapeutics. If a tube is placed with the target -the source of X-light- ten centimetres from the skin, the diseased area to be treated being ten centimetres below the surface, the superficial tissues will be exposed to a radiation about four times as intense as the deeper tissue; with the result that the diseased tissue cannot be exposed the proper length of time, for the skin will be destroyed. If the tube had been placed at two hundred centimetres from the skin, the intensity of the radiation falling on the skin would have been but slightly more powerful than that reaching the tissues below, provided the radiation was from a high-resistance tube. Therefore the treatments could have been longer and more effective, for the risk of burning the superficial tissues need not have been considered. On the other hand, if we wish to treat diseases of the skin, and place the tube far away, we expose the underlying tissue to a radiation of practically the same strength as the skin, obviously not a scientific procedure. Therefore the correct method in treating a disease of the skin or superficial tissues is to have the target -the source of X-light- as near the skin as possible. One of the arguments that has been brought forward for considering ultra-violet light superior to X-light in some affections of the skin and superficial tissues has been that the action of the former being limited to the surface, or near it, the underlying tissues are not so likely to be injured. With the forms of tube in use -focus tubes- it is impossible to bring the source of light -which is in the middle of the tube- near the skin, as the tubes have a diameter of about sixteen centimetres. If the tubes were brought in contact with the skin, the source of light would still be eight centimetres away. Even this distance is less than recommended in the text-books. For example, Williams, in Roentgen Rays in Medicine and Surgery, says: "In cases of new growths the tube should be brought within fifteen or twenty centimetres of the part, in skin diseases the distance should be greater." Pusey, in The Roentgen Rays in Therapeutics and Diagnosis, says: "The distance at which I place my tube is, as I have said, fifteen to five centimetres from the surface." Add to these measures six or eight centimetres to get the distance of the source of X-light from the skin. These two books have been selected not because the ideas advanced differ from those of others, but because they may be supposed to be representative. Let us take twenty centimetres, then, as a fair average of the distance now used between the source of X-light and the skin in therapeutics. Is it not obvious both the form of tube and the method of use can be improved upon, for with the source of X-light at this distance when a disease of the skin is treated, the underlying healthy tissues are subjected to an unnecessarily strong radiation? A tissue at a depth of a centimetre has nearly as strong a radiation shining on it as the skin, taking no account of the light lost in absorption by the upper layers, which is considerable, however.

In treating diseases of the skin and superficial tissues the source of X-light should be brought as nearly in contact with the skin as possible and the radiant area should be large. For example, suppose the source of X-light could be brought within one millimetre of the skin in treating a skin disease. It is obvious the tissues one centimetre below the surface would be subjected to X-light whose intensity would not be more than one-hundredth of that striking the skin. Certainly a better plan than the one first mentioned. Tubes enabling this to be done are not shown for the reason given in Note 146, where the principles for producing a diffused source of X-light almost in contact with the skin were mentioned. It may, however, be well to speak of two general forms which are valuable. Cylindrical tubes, with the end opposite the cathode made flat, and funnel-shaped tubes, with the wide end of the funnel opposite the cathode and flat, for treating large areas. In these tubes the flat ends received the impact of the cathode stream particles over their whole surface, X-light in consequence arising from the whole area. It is well to cover the flat ends with thin aluminum foil to act as anodes and yet allow the X-light to pass through. In all cases we should remember X-light spreads as a spherical wave from every surface struck by a cathode stream particle, and therefore all X-light tubes of every kind should be enclosed in non-radiable cases. The cases used about the tubes recommended for skin diseases should have handles to enable them to be readily held in the hand and applied to the diseased area, or moved about over it when it is too large to be covered by the end of the tube. Such tubes may have broad targets of aluminum within the glass, or the glass wall itself may be the target, the outer surface being coated opposite the cathode with the aluminum foil, and connected with the position terminal of the generator; for Lodge and Rowland showed that a target which was an anode was most efficient.[158] The reason was given in Note 66, October 25, 1899. Also in designing such tubes the experiments detailed in Notes 15 and 102 should be remembered, as they showed, contrary to the statement of Crookes, that the position of the anode did to some extent determine the direction of the cathode stream in high vacua. For example, in designing a tube, if the anode is placed in a side arm, the cathode stream being sent directly forward past this arm to the other end of the tube, the anode will tend to deflect the stream

[158] For the principle on which an efficient X-light tube can be constructed without the target being directly an anode, refer to Note 31.

and to retard it when it has gone beyond the side arm. This will make the cathode stream particles when they strike the glass less efficient sources of X-light, for their velocity of impact will be reduced. Consult Note 18, January 26, 1898. On the other hand, if this part of the glass is made an anode, the efficiency of the tube is increased. When it is desired to cool the end of the tube in contact with the skin, the method illustrated in Note 41 is a good one. A sheet of thin soft rubber may be tied over the flat end of the tube, and quiet or circulating water kept between it and the tube. In determining how to use X-light in treating diseases which are to be reached by allowing the light to enter through some of the body cavities, like the mouth or rectum, we should consider how far below the surface of the membrane of the cavity the diseased tissue lies. If we wish to treat a superficial disease of the membrane of the cavity of the mouth, for example, a diffused radiant area tube in which the glass wall is the source of X-light should be used, as in this way the source can be brought almost into contact with the diseased tissue, — the distance need not be more than two millimetres. If, on the other hand, the cavity is to be used as a way of approach to deeper-seated tissues, such a course would be unscientific for a reason given; namely, the strength of the X-light on the healthy surface tissues of the cavity would be out of all proportion to that shining on the diseased tissue to be affected. In such a case the X-light concentrators and reflectors described in Notes 144 and 156 should be used, for with these the source of X-light may be far away, therefore the healthy tissues will be subjected to a radiation but little stronger than the diseased ones. This note is closed with a few more axioms. In using X-light in therapeutics its wave-length should be such as will cause it to be absorbed by the diseased tissue. The denser the tissue the shorter the waves may be — important in treating diseases of the bones[159] without injury to the overlying tissues. In using X-light in therapeutics the waves should be as long as can be employed without injury to the overlying tissues, — such waves are most absorbed. In using X-light in therapeutics the distance of its source from the surface of the body through which the X-light enters should vary directly with the distance of the diseased tissue below that surface, — the nearer the disease to the surface the nearer the source of X-light. In using X-light in therapeutics the distance of the diseased tissue below the surface of the body through which the X-light enters should determine the form of vacuum tube to be employed, — the nearer the diseased tissue to the surface through which X-light enters, the nearer the source of X-light should be to the wall of the tube. — Electrical Review, August 1, 1903.

NOTE 168 — ON TREATING TWO PATIENTS AT THE SAME TIME WITH THE SAME X-LIGHT TUBE

In hospital work the number of patients who desire to be treated by X-light is greater than can be served. Therefore attention is called to the use of a special form of tube which was il-

[159] Premature wasting of the bone sockets in teeth for example, — with or without the formation of pus.

lustrated in Plates 28 and 31, Figures 58 and 60, Note 65, September 20, 1899. This tube was a modification of one illustrated in Note 17, Plate 6, Figure 2, January 12, 1898. The principle on which they were constructed was to send one of the cathode discharges -if an alternating current was used- against the back of the target, thus throwing the X-light arising from its impact out of the field to prevent injury to the definition. But the tube is useful in therapeutics, as one patient can be placed on one side of the tube and another on the opposite, each receiving the X-light, one from the back, the other from the face of the target. The tube must be in a non-radiable tube holder with two diaphragm plates with adjustable openings. For these simple therapeutic purposes a less expensive tube stand and diaphragm can be employed. The tube box should be attached on the under side to an upright post sliding within a vertical tube to permit of adjusting the height of the source of X-light and allowing rotation in a horizontal plane. These two movements are all that are required in using such a tube in therapeutics, for only the more accessible diseased areas should be treated with this form of apparatus. As in therapeutics, the X-light need not arise from a small radiant area, the surface of the target may be prevented from melting without using the cooled target shown in the figures mentioned, by making the cathodes of such shape that the cathode streams are not brought to a focus on the target, but are caused to strike it over a large area, the surface of the platinum being made larger, as in Plate 123, Figure 1. A simple form of apparatus may be used for exciting these tubes; namely, one of my variable potential coils, excited by a current from an alternating dynamo without any interrupter.[160] This form of apparatus requires little attention and is satisfactory for some therapeutic work in hospitals where apparatus should be simple and cheap to enable many patients to be treated. One dynamo can be used for a number of coils. — Electrical Review, August 1, 1903.

NOTE 169 — A SHUTTER FOR AN X-LIGHT TUBE BOX

In earlier notes the advantage of using a shutter in taking photographs by X-light was shown, and figures given of shutters; the one to be described is a more convenient form. Plates 124 and 125, Figures 1 and 2, are photographs of the shutter. Plate 124, Figure 1, is a detailed front view of the tube-box slide -consult Notes 149, 155, and 156-, with the opening of the diaphragm plate exposed by the action of the shutter. Plate 125, Figure 2, shows the same opening closed that no X-light may escape from the tube box. Plates 126, 127, and 128, Figures 3, 4, 5, 6, and 7, are drawings to explain the mechanism. Plate 126, Figure 3, is a view of the back of the shutter, the slide of the tube box having been removed. The leaf SL which closes the hole in the diaphragm plate is made of mahogany with a depression filled with white lead and japan until opaque to X-light. The moving force is a strong spiral spring SP, Plate 126, Figures 3 and 4. One end is attached to the axis of the cam C, which moves the leaf SL, the other to the fixed support FS, attached to

[160] Refer to Notes 149 and 179 D.

the hard rubber plate supporting the mechanism of the shutter. Tension is made on the spring by turning the handle forming the head of the axis of the cam shown in Plates 127 and 128, Figures 5, 6 and 7. To prevent the action of the shutter from uncoiling more than one turn of the spring in closing the opening of the diaphragm plate, a stop ST is employed, Plates 127 and 128, Figures 5, 6 and 7. To allow the spring to be wound to the proper tension, the stop is turned back as shown by the dotted lines in Plate 127, Figure 5. The shutter is ready for use -with the leaf SL closing the opening in the diaphragm plate-, when the hook HK, Plate 127, Figure 5, is in the very shallow notch NH. To open the hole in the diaphragm plate a rubber bulb attached to the rubber tube RT, Plate 127, Figure 5, is pressed. The air which is driven from the bulb enters the metal cylinder CY, forcing forward a piston that by the force of its impact drives forward the arm AP to the position shown in Plate 127, Figure 6, releasing the hook HK from the notch NH, thus allowing the spiral spring to turn the leaf SL until the opening of the diaphragm, Plate 124, Figure 1, is exposed. The hook HK, Plate 127, Figure 6, strikes against the catch SC, causing the opening of the diaphragm plate to remain exposed. To close the opening in the diaphragm plate, to shut off the beam of X-light, a second impulse is given to the bulb, which forces the arm AP forward to the position shown in Plate 128, Figure 7, lifting the hook HK from the notch SC, Plate 127, Figure 6, allowing the leaf SL to close the opening in the diaphragm plate. When a more rapid action of the shutter is wanted, the catch SC is turned up by means of a hinge. One impulse of the rubber bulb will then open and close the hole in the diaphragm plate. This shutter has been fully illustrated to make the construction so evident an ordinary mechanic could make one for any physician who was convinced of its utility. It is useful in photographing the chest and is well suited for some therapeutic purposes, especially in tube boxes containing X-light tubes of the type described in Note 168 and used in treating two patients at one time. In the latter case the tube box requires two shutters.

Electrical Review, August 8, 1903.

NOTE 170—ON PREVENTING WATER VAPOR FROM ENTERING THE MERCURY PUMP USED IN EXHAUSTING X-LIGHT TUBES

In exhausting X-light tubes the presence of water vapor in the pump delays the production of a vacuum. Keeping the pump warm was recommended in earlier notes. In the present note apparatus will be described for keeping water vapor out of the pump. Considering how many able men have worked with mercury pumps, it is a little strange water vapor has been allowed to enter the mercury reservoir at every stroke of the pump and to pass up between the mercury and the inner wall of the fall tube into the pump chamber, where it has delayed the production of a vacuum in any apparatus attached to the pump. Plate 129, Figure 1, is an illustration of a mercury pump copied from the latest work on gases,—The Study of Gases, by Travers. The pump reservoir PR, containing mercury, is in free contact with the air.

The results mentioned follow, particularly in the morning, when the temperature of the pump room is made higher than at night. Under these circumstances, when the pump is operated water may be seen in minute drops to collect between the mercury and the inner surface of the fall tube. If an X-light vacuum was left in the pump, it may have deteriorated, and bringing it back to the degree it was left may take some time, as the water continues to enter the pump chamber with the rise and fall of the mercury. This increase in pressure has been attributed to leaks in the pump, and to fine defects in the seals of the X-light tube.

The difficulty can be made less by placing a drying arrangement in the path of the air entering the mercury reservoir. To avoid rapid deterioration of the drying chemical, it is desirable to close the air inlet with a flexible diaphragm which can expand and contract as the mercury flows into or out of the reservoir. A simple method of applying the principle to the mercury reservoir of the pump shown in Plate 129, Figure 1, is illustrated in Plate 129, Figure 2. The mouth of the reservoir is closed by a rubber stopper through which passes a T-shaped tube, on one end of which is a drying bulb, on the other, a tight rubber bag. As no external air enters the pump through the mercury reservoir the contained air is kept dry by the drying chemical. To insure rapid work a mercury pump for exhausting X-light tubes should have a large pump head. Forty kilogrammes of mercury is a considerable mass to have in a glass reservoir, therefore pump reservoirs should be made of iron. One of this kind is shown in Plate 129, Figure 3. Drying tubes should be also placed at the outlet of the pump.

Electrical Review, October 17, 1903.

NOTE 170 A—FURTHER PRECAUTIONS IN USING X-LIGHT IN DIAGNOSIS

In former notes attempts were made -by describing experiments on animals- to show X-light was a dangerous agent and to explain methods of diminishing the risk to the patient and physician. Some of these methods have already been sufficiently described. In the present note, the matter is further considered. As X-light is a dangerous agent, it should be allowed only to shine through the tissues under examination. The total amount striking these tissues during a given time should be the smallest which will allow an accurate diagnosis to be made. The time will come when physicians will realize no examination of the chest is adequate unless the organs are seen by X-light. Then with these examinations advantage will be taken of the time during which a fluorescent screen gives light, and of the persistence of vision to reduce the total amount of X-light required to make the diagnosis. The best way to do this is the one already recommended in earlier notes for prolonging the life of a tube used in such examinations; namely, sending the electric current in surges each of very short duration, producing pulses of X-light, that persist as fluorescent light on the screen and in the eyes, allowing intervals between the surges during which, though the light appears continuous to the eye, no X-light is shining on the tissues.

Boston Medical and Surgical Journal, October 1, 1903.

NOTE 170 B—SOME PRINCIPLES INVOLVED IN THE THERAPEUTIC APPLICATIONS OF RADIO-ACTIVITY

In 1900 experiments were made on animals to determine the value of radio-activity in diagnosis and therapeutics. The results as relating to diagnosis were briefly referred to so far as they were apparent with radium 1,000 in a paper, The Cathode Stream and X-Light, in the American Journal of Science for November, 1900. With the more powerful radium now available the results may be different.[161] No report of its therapeutic uses was made at that time, but radium 1,000 was made into capsules, with non-radiable walls to limit the action to the diseased tissue. These were given to Dr. Williams, and recommended for use in treating lupus and superficial cancers. Later -1901-, radium of greater strength was used. As the experiments on animals had shown radium to have a potent effect on tissue, attention was called to its use in therapeutics in the Boston Medical and Surgical Journal for January 23, 1902, while waiting for Dr. Williams to report his experience. Now an American company has been formed to extract radium from carnotite, radio-active substances are certain to attract more interest in the therapeutics of the future, when ether waves and emanations will receive attention in the medical schools, professorships of ether and radio-active therapeutics being established; therefore it may be well to mention some precautions, after stating a few facts about radium, which is selected as a type of

[161] The results with pure radium bromide are the same.

radio-activity. The Curies, who discovered radium and polonium, found radium gave off ether waves of various lengths, — some long enough to affect the eye as light, others longer, or heat waves. In addition to ether waves, the Curies and Becquerel have found radium sends off particles of various sizes: A-particles, about the mass of hydrogen atoms, which constitute ninety-nine per cent of the radio-activity. These have positive charges. They are easily absorbed by thin layers of matter; cardboard, for example. Their activity is reduced one-half by aluminum five one-thousandths of a millimetre thick. They are about one hundred times as hard to deviate in a magnetic field as the next form, or B-particles, which are only a thousandth as large, negatively charged and supposed to be the same as the cathode stream particles in an X-light tube. They penetrate further into substances, being reduced in intensity one-half by aluminum half a millimetre thick. The third form of activity, or gamma rays, have not yet been certainly deviated by a magnet. They are very penetrating, their intensity being reduced one-half by aluminum eighty millimetres thick. Whether they are ether vibrations or flying particles is not certain. For the present when using radio-active substances in internal therapeutics the substances cannot themselves be employed, on account of their high price. Advantage must be taken of the investigations of physicists like Rutherford and Soddy,[162] who

[162] Radium chloride is a better salt than radium bromide for the production of emanations for use in internal medicine (Soddy's theory), as the latter decomposes slowly in air or water. The gas liberated from the aqueous solution

have shown when a radium salt is dissolved in water it gives off "emanations," which can be collected in air in a gas holder over mercury and used in internal medicine as first recommended by Soddy. When radium is dissolved, seventy-five per cent of its radio-activity is at once liberated, the twenty-five per cent remaining consisting of A-particles. When the first rush is over, radium in solution is constantly giving off more emanations, the amount being as great as in the dry state. This is important to remember, for it shows radium in solution can be depended on as a constant source of emanation to be used in therapeutics. Even the emanation itself can be employed to produce fresh radio-activity. If a small volume of air containing the emanation is put into another gas holder containing air, the whole volume will rapidly become radio-active, the intensity increasing until balanced by the rate of decay through the metal holder. In this connection it may be well to mention that radio-activity is an attribute of many substances; all the common metals, for example, show it. From mercury Strutt has obtained so radio-active a gas as to make it probable that part of the therapeutic action of this metal is due to radio-activity, and this may be true of other substances now used in therapeutics. Air enclosed in cylinders of common metals like copper, tin and zinc becomes radio-active.

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consists of a mixture of hydrogen and oxygen in the proportion of two parts of the former to one of the latter, according to Bodlander. This change is not an ordinary chemical reaction, as the quantity is many times too great. Radium carbonate also produces the same evolution of gas.

One writer has proposed placing a glass tube of radium in the middle of a cancer. The experiments on animals, which have been mentioned, indicate this would be unwise, for before the peripheral parts of the new growth were affected, the destruction of both healthy and diseased tissue near the radium would have resulted, for the intensity of the action varies roughly as the square of the distance from the radium, therefore the tissues within a millimetre of the radium would receive twenty-five hundred times as powerful a treatment as those five centimetres away,[163] and the continued presence of the radium, which would be necessary to affect the peripheral parts, would prevent the formation of fresh healthy tissue in the interior. But it is with reference to diseases on or near the surface that the results of the experiments on animals will be considered now, and when radio-active substances are used for this purpose, the following precautions are to be observed: As the radiations and emanations of the radio-active substances spread in all directions, and some of them have destructive powers on animal tissues, the radio-active substances must be used in tubes, cases, plasters, etc., with non-radiable walls, that the activity may escape only in the required direction and be reinforced by the induced radio-activity from the inner surface of the container. This precaution is necessary to prevent injury to the physician and healthy tissues of the patient. Particular attention must be given, as with X-light, to the protection of

[163] Even more than this, for the beta rays which are believed to contain the most therapeutic power are rapidly absorbed by the tissues.

the eyes, for animals can be made blind by radio-active substances, as well as by X-light. In using the radio-active substances in diseases of or near the skin, the depth of the diseased tissue to be affected must determine the distance of the radio-active substance from the surface of the patient, for the reason mentioned, — activity diminishes approximately as the square of the distance, though really more rapidly on account of the complex nature of the activity. If the radium is placed ten centimetres from the skin, the intensity at a depth of one centimetre is nearly as great as at the surface for the more penetrating forms of activity. In many cases, therefore, the sound tissues below the diseased will be acted upon by a destructive agent whose activity would be nearly as great as at the place of disease.[164] The correct way in treating a skin disease with a radio-active substance is to consider to what depth it is desirable to confine as far as possible the activity. If to a slight depth, the radio-active substance should be almost in contact with the skin, the duration of the application being of proper length but always shorter than when at a greater distance. In this case healthy tissue at a depth of one centimetre would be acted on by radiations whose intensity would be less than one-hundredth of those striking the skin; obviously a more scientific method.

In regard to the construction of containers for limiting the radiation to the area to be treated, the plan of wooden cases, either stationary or held in the hand and made non-radiable by

[164] In this case the alpha and beta rays are supposed to have been filtered out.

paint, composed of an oxide of a heavy metal like lead, which were recommended in using X-light, may be employed, metals being substituted for wood, as the fact of their being conductors of electricity is unimportant. Any heavy metal, lead, for example, is suitable.[165] When radio-active substances are used in the form of plasters which require to be flexible to allow them to be adapted to the patient, the back of the plaster should be of material which is made fluorescent by the radio-active material, for in this way the unused radiations are rendered less destructive. Professor Barker of Philadelphia suggested several years ago that the radio-active substances might take the place of X-light in surgical diagnosis. On the strength of his statement the experiments mentioned were made with radium 1,000; though with this the results were unsatisfactory, it would be well to repeat the experiments with pure radium bromide, which can now be purchased by any rich person.[166]

Boston Medical and Surgical Journal, November 12, 1903.

NOTE 171 — ON X-LIGHT TUBES IN WHICH AN INTERNAL TARGET IS COOLED

Several makers have adopted the plan originated during these experiments of cooling an internal target in an X-light tube, but owing to want of experience they have failed to copy the

[165] Owing to the great penetrating power of the pure radium salts, the substance must be thicker than when using X-light from ordinary generators.

[166] Through the kindness of Dr. F. H. Williams an experiment was tried with pure radium bromide. The results were the same as were obtained with radium in 1900 and already mentioned. Good views of the bones were not seen.

more efficient types, making inferior forms of the earlier and less valuable, in which the target was cooled by a small reservoir of water attached to the X-light tube, instead of by a constant discharge of air or water against the target. The tube illustrated in Plate 130, Figure 1, is a type of what a water-cooled tube should not be. It is illustrated because in a recent work on X-light this statement is made in regard to it, "Of the water-cooled tubes this is unquestionably the most effective." When this tube is excited by a powerful current the water is driven from the target, which the heat then melts, or the tube cracks at the seal. A second objection is the impracticability of sending the X-light in some of the required directions. No tube is suitable for medical use unless the X-light can be sent up, forward or down at any angle. With this tube the light cannot be conveniently thrown upward, as it should be when examining a patient in a horizontal position with the source of X-light below, because the cooling liquid falls away from the target by gravity, allowing the target to heat. If manufacturers of cooled target X-light tubes do not wish to adopt the plan shown in Note 1 of using an air or liquid stream from a source outside the tube, they should copy the idea used in the earlier forms of this tube, for, as shown in Plate 131, Figure 2, it allows the X-light to be sent in any direction, as the cooling arrangement being attached to the tube by a rubber or oak bark stopper permits the reservoir to remain vertical while the tube is turned about its long axis to cause the light to shine up, forward or down at any angle. When electrolytic breaks are used with coils of the type shown in earlier notes, in which a large amount of current can be safely employed, even the better type of cooled target tube illustrated in Note 1 may require a different arrangement of the cooling device, if this is a liquid, to diminish the risk of injury to the seal. In some of the later forms the hollow target was made longer, the glass and platinum at the seal being kept at a more uniform temperature by the arrangement shown in Plate 131, Figure 3. This modification is not required when the target is cooled by an air blast. Though my experiments have shown the practicability of producing X-light of proper quality in sufficient quantity to show the heart clearly at a distance of ten metres with a current which does not melt a thin uncooled platinum target, generally a current is used sufficient to convert into vapor the water touching the target, which melts, admitting air to the tube. The way to prevent this is to discharge the cooling agent in a constant stream directly against the target. Cooled target tubes in which this is not done are not better than those with rotary uncooled targets, such as have been shown in these notes. — Electrical Review, November 14, 1903.

NOTE 173 — FURTHER REMARKS ON APPARATUS REQUIRED IN PUMPING X-LIGHT TUBES

To any one who has studied the history of the mercury pump, the difficulty of saying anything new will be evident. About the only originality which can be shown is in a judicious selection and combination of valuable features, useless ones being discarded. The former are few, the latter so many it seems as if the object had been to complicate the pump. If it is important rapidly to obtain the highest vacuum, the pump and vessel to be exhausted should be of one piece of glass without joints, drying tubes, gauges or stopcocks; the pump and vessel to be exhausted being hot. When the calibre of the pump increases or diminishes, the change should be gradual, to allow the mercury to sweep off gases and vapors from the glass. A pump of this kind might be called the Swedenborg-Mile-Rood-Pump, for Swedenborg invented the first mercury pump in 1722, Mile added the barometric tubes on the inlet and outlet, and the rising and falling mercury reservoir in 1828. Rood, in 1880, showed that the pump should be hot. If all the other men who have worked on the hand-mercury pump had never existed, it would to-day be as efficient. As the highest vacua are of no value in X-light tubes, though supposed to be necessary, a pump for exhausting them may well have its efficiency slightly diminished if it is made more convenient. A pump of this kind suited especially for experiments where it is desirable to collect the gases or measure the degree of exhaustion is shown in Plate 132, Figure 2. Mile's barometric tube on the inlet is replaced by a short, wide tube IT with a stopcock IS, only a little above the outlet tube. This construction was made possible by the invention of the automatic valve AV by Mitscherlich in 1873. In his valuable pamphlet, The Development of the Mercurial Air Pump, Thompson states, on page 23, that a stopcock between the vessel to be exhausted and the pump is worse than useless. As the experiments mentioned in these notes could only be made at night, on account of daily professional duties, it was necessary to economize time in pumping the X-light tubes. Preventing water vapor in the air from entering the pump -while standing unused-, by means of a stopcock IS on the inlet tube, was found to reduce the time required to exhaust the tubes. This is so important it will be stated as another X-light axiom, — water vapor should be kept out of the mercury exhaust pump.

Before the stopcock IS is opened, most of the water vapor should be removed from the X-light tube by heat and a small hand exhaust pump, attached by a flexible rubber tube at WVO, a partial vacuum being produced. The tube S is then sealed; IS being opened and the exhaustion finished with the mercury pump. Where the latter is not worked by hand, as in the figure, but by a mechanical pump, as recommended in Note 138, the preliminary exhaustion should be directly into the mechanical pump. One never sees a mercury pump without a drying tube between the pump and the vessel being exhausted. Usually it is sealed to the pump as shown in Plate 129, Figure 1, Note 170. The temptation then is to allow the drying salt to remain too long, for the pump must be taken apart before new drying salt can be introduced. If a drying tube is used, it should be attached by a ground joint, as imaginary leaks from such joints do less harm than damp drying salt.[166A] Details of apparatus for preventing water

[166A] Mechanical pumps -without drying bulbs- have been used for exhausting X-light tubes. Some of the earliest X-light tubes made in Boston by my friend Mr. W. E. Oelling in 1896, at the works of the Beacon Lamp Co., were exhausted in this way.

vapor from entering the pump from the mercury reservoir having been given in Note 170, only the method of applying the principle to the pump outlet will be here considered. In Plate 132, Figure 2, Mile's barometric outlet tube PO ends in a vessel MC provided with a tight cover C containing three openings, two of which are closed by rubber stoppers, the third by a rubber tube ORT which makes an air-tight connection between the Mile's tube PO and the vessel MC. Through the first rubber stopper passes the tube OVT, closed at the outer end by a valve OV and filled with drying salt DS. The end of this tube within the vessel MC extends down over the upturned end of the Mile's outlet tube. As the mercury rises in the pump chamber, it flows over, appearing at the end of the Mile's outlet tube, escaping into the vessel MC; the air from the pump rising through the tube OVT, passing out by the valve AV. As the mercury falls in the pump chamber, the valve closes, excluding the outer air, the retained air being freed from moisture by the drying salt. The soft rubber cylinder ORT connecting the Mile's tube PO with the vessel MC collapses, allowing the mercury to rise again by atmospheric pressure into the Mile's tube. When it is necessary to collect the gases from the vessel being exhausted, the tube OVT, with its rubber stopper, is removed, a vial of mercury being inverted over the upturned end of the Mile's tube and held in place by a rubber band, causing it to fit the hole in the top of the mercury cistern MC. For details of methods of introducing the collected gases into spectrum tubes, refer to Travers' valuable work, The Study of Gases.

In some of the experiments mentioned in earlier notes, while attempting to find out the nature of the gases in the cathode stream, they were collected in this way. Later a surer path was taken. The X-light tube was made the spectrum tube also, by a movable target. The third rubber stopper supports a drying tube DB which keeps the air in the mercury cistern MC dry. No gauge is shown on the pump, for the degree of the vacuum can be measured by having a mark near the upper part of the Mile's outlet tube, and making the necessary calculations. This form of pump, while well suited for investigations on X-light tubes in which it is desirable to collect the gases, is not to be recommended for routine work, as the capillary is liable to fracture, and care is required to prevent bubbles from rising through the capillary to the pump chamber. In Plate 133, Figure 2 A, this capillary tube PO, Plate 132, Figure 2, is replaced by an automatic valve AV2, which, like the similar one on the inlet -AV, Plate 132, Figure 2- is the invention of Mitscherlich -1873-. When this form of pump is used, the pump cannot itself be a gauge, but this is no objection in a pump intended only for routine exhaustion of X-light tubes, therefore no gauge is shown in Plate 133, Figure 2 A. A drying tube like that in Plate 132, Figure 2, at OVT should be attached to the pump outlet at OVT 2, Plate 133, Figure 2 A, and a stopcock IS 2 with a mercury seal, to prevent water vapor from entering the pump when standing unused. A pump of this kind should be called the Swedenborg-Mile-Mitscherlich. These are the only men whose work on the hand-mercury pump has been essential, but to a pump with shortened fall tube to be mechanically operated, the name of Robinson should be added. His form is more convenient than a hand pump, if power is available, as the mercury reservoir may be placed within the pump closet, rendering the warming of the mercury simpler.[167]

Heating Arrangements. — In earlier notes the necessity of keeping the X-light tube hot was repeatedly mentioned. An arrangement used in the experiments and already described, is here illustrated. In Plates 132, 133, and 134, Figures 2, 2 A, and 3, is shown a tube oven -TO- with non-radiable walls. Its dimensions are sixty by seventy-five by seventy-five centimetres. It is lined with asbestos. There are two doors, D and DI, each of which has a window of mica M and MI. The mica windows have doors D 2 and D 3 glazed with heavy lead glass, three centimetres thick or more. The X-light yielded by the tube can be seen through the mica windows. When this is not necessary, the mica windows are covered by the glass doors to prevent the operator from being injured by the X-light while pumping and tuning the tube. The importance of this precaution has already been sufficiently pointed out in former notes. One end of the X-light tube is attached to the pump by the tube OT, Plate 132, Figure 2, the other end being supported by the glass stirrup GS, Plate 134, Figure 3, which can be adjusted. The means of heating the oven are shown in Plate 134, Figure 3. B is one of three gas or kerosene burners. The heat ascends, as indicated by the arrows. PHC,

[167] Mechanical pumps are superior to mercury pumps in one respect, — they do not introduce mercury vapor.

Plates 132 and 134, Figures 2 and 3, is the pump closet. The door GD, Plate 132, Figure 2, is glazed to allow the pump to be examined and folds in the middle to admit of partial opening, when necessary to reach the pump, and yet prevent too much cold air from entering. The warming arrangement is shown in Plate 134, Figure 3, at LB. Both oven and pump closet are provided with thermometers [168] which can be read from the outside. Sufficient details for pumping have been given in earlier notes, particularly in Note 138.[169] Directions for operating pumps may be found in the work already mentioned. In former notes it was said the emanations from the pump should be prevented from entering the X-light tubes during pumping, directions being given for accomplishing this. One means was to place a loose plug of gold foil in the tube going to the pump, to absorb mercury vapor. This is shown in Plate 132, Figure 2, at GF. Another was to insert a wire in this outlet tube, the wire being grounded. This is shown in Plate 132, Figure 2, at GW. In many of the experiments, the coil was grounded for the same purpose. In former notes it was said an X-light tube should be exhausted and subjected to the same current, before it was sealed,

[168] It is necessary not to use too high a temperature in the pump oven, on account of vaporizing the mercury.

[169] The discharge from the secondary of an induction coil at the time when the current begins to pass through the primary causes the anode to act as a cathode, blackening the tube from the platinum torn off from the metal. Therefore in exhausting an X-light tube, when the terminals are being electrically treated to remove the proper amount of amalgamated gas, there should be spark-gaps in series to prevent the inverse discharge through the tube.

that would afterward be used in exciting it, and as it was difficult to obtain satisfactory tubes for powerful apparatus, the suggestion was made in Note 68 to hospitals where X-light was much used, to have their own pumping arrangements. For these reasons, the pumping apparatus here shown is portable, the pump being worked by hand, the weight of the mercury reservoir being balanced by a lead weight illustrated in Plate 134, Figure 3, at CW. The pump here shown is made of glass, the material always employed. It might be well to try to make a metal pump. Seamless polished steel tubing can now be obtained, and the beautiful electrical welding process, of Professor Elihu Thomson, would enable a pump to be made in one piece, the inner sides of the welds being ground smooth and polished. In order to attach the X-light tube, the glass tube connecting it to the pump could be sealed to a seamless platinum tube united with the pump. A pump of this kind, instead of being a delicate instrument most suitable for the laboratory, might be a commercial machine.

NOTE 174—RADIANT AREA FINDER[170]

In earlier notes X-light tubes in which the walls were the source of X-light were recommended for therapeutic purposes, the form and position of the cathode determining the position and size of the radiant area.[171] Before using such tubes, it is desirable to test them to see if

[170] No originality is claimed for the principle of this finder.

[171] Refer to Notes 166 and 167.

the X-light is given off from the calculated area. For this purpose, a brass tube covered with lead and containing diaphragm plates and a fluorescent screen is useful. The tube is one metre long and twenty-five millimetres in diameter. One eye is applied to the eye-piece of the tube, which is directed toward the radiant area, until a round spot of light is seen on the fluorescent screen. The other eye sees the direction in which the tube is pointed, which is the line of the ray of X-light. By moving the tube about, a mental picture is obtained of the size and position of the radiant area. In earlier notes the necessity of using the X-light tube in a non-radiable box was shown, no X-light being allowed to strike the observer. When investigating X-light tubes this box cannot always be used. In these cases, the observer must protect himself in the way already recommended by non-radiable coverings. In Note 116 C, a covering of this kind was described which was made by coating cloth with a flexible non-radiable paint. As one person has thought well enough of this idea to ask for the formula for the paint, it is given here.[172]

[172] Flexible non-radiable paint for coating cloth coverings to protect from X-light: White lead paint, 9 pounds; soap, $2\frac{1}{2}$ ounces; water, 12 ounces. Heat the water to 212 degrees F., dissolving the soap in it. Pour the mixture while hot into the paint, stirring until well mixed. As this paint comes off slowly after a time, a better way is to mix dry powdered white lead with rubber dissolved in benzole, spreading the mixture between two sheets of cotton cloth, which are then pressed together. This method protects the non-radiable coating. If lead is considered undesirable, a bismuth compound can be used mixed either with a drying oil or rubber dissolved in benzole, but a greater thickness is required.

The idea of using paint of this kind as a protection from X-light arose after seeing it employed by Mr. C. A. Welch on the coverings for sails, which need to be flexible and waterproof. Experimenters with X-light will find a long white duck coat, of the kind used by marketmen, a convenient garment when coated with this paint. A pair of white cotton or thin rubber gloves, recommended in earlier notes, should also be painted in the same way and used to protect the hands. They soon break up the unwise habit of employing the hands as a test of the strength of the X-light. The lower parts of the body are easily protected from the direct X-light by a non-radiable table placed below the tube which is being studied, as the shadow it casts covers them.

Electrical Review, December 12, 1903.

NOTE 175 — DESIGNING X-LIGHT TUBES

The tube shown in Plate 135, Figure 1, is of the type illustrated and described in Note 138. The centres from which the curves are struck and the length of the radii are given. The vacuum regulators operate on the principle first embodied in my tubes and later described in this series of notes, that of having two regulators, one a regenerator [173] to lower permanently

[173] As it seemed possible that one cause for the deterioration of X-light tubes by use might be that some of the charged particles formed during the action of the tube passed out through the glass well, the tubes were kept in an enclosure with radium salts to see if the charged particles shot off from the radio-active material might not by passing into the tube supply the loss. The experiment should be repeated now with pure radium bromide, which can be purchased by any rich person.

the resistance of the tube, the other to lower the starting resistance and then automatically keep the working resistance of the tube at any desired point. The importance of being able always to regulate the light during an examination is so great it has been much dwelt upon and made an X-light axiom.

In the tube shown in Plate 135, Figure 1, both regulators are operated by the generator used to excite the X-light tube. When the tube is to be used, the regulators are arranged as shown in Plate 136, Figure 2. The current then does not go through the permanent regulator. It goes from the electric generator through the arm A to the wire B, the spark-gap S, the automatic regulator AR, the stem of the terminal C, to the electric generator. To regenerate the tube, the starting resistance is reduced to any determined point, for example, one hundred and fifty millimetres, by the automatic regulator, to prevent risk of puncture. The stem A is then lifted quickly -to the position of the dotted line A 2-, the regulator HR put into the circuit -by turning the arm HW down into the position shown by the dotted line HW 2-; the current going through the stem of the terminal T, the wire HW 3, the regulator HR, the wire HW 2, the wire B, the spark-gap S, the automatic regulator AR, the stem of the other terminal C to the electric generator, until the resistance of the tube is less than one hundred and fifty millimetres, when the current will leave the regulator and regenerator circuits, passing through the X-light tube between the faces of the terminals, the regulators ceasing to operate. The arm HW 2 is then raised, cutting off the current from the regulator HR. The arm A is brought in contact with the terminal disk TD fully described in earlier notes. The current then goes through the automatic regulator; the resistance of the tube being maintained at any point less than one hundred and fifty millimetres by the length of the spark-gap S which is controlled by a handle RH -Note 149, Plates 102 A and 103, Figures 5 and 5 A-, and described in Note 152. The handle is within reach of the operator while making an examination or taking a photograph. The kind of X-light can therefore be varied without interrupting the examination. As the X-light tube is intended for use in a tube box -illustrated in Note 156-, provision must be made to prevent the spark-gap from cutting off any of the X-light escaping through the openings of the diaphragm. In the tube illustrated in Note 138 this was effected by having the stem of the target arranged to allow the latter to face in several directions. If this idea is not used, the spark-gap tube should be placed at an angle. The regulator and regenerator are both somewhat alike in appearance. One contains a chemical which liberates a gas that it reabsorbs, while the other liberates a gas which it does not reabsorb. The tubes in which the chemicals are placed are shown in Plates 136 and 137, Figures 2 and 3. Each form has a platinum wire sealed into one end. Another wire may be sealed into the other end, or the end may be open, the opening serving for the introduction of the chemical, in a powdered state mixed with a conducting substance, gold foil, for example, as described in Note 139. The opening, whether in the side or the end, is closed with spun glass.

This construction of regulators and regenerators is useful in employing the gases, helium, for example, which are contained in minerals, as the high temperature produced in the interior of the powdered chemical by the current as it jumps from one bit of conducting material to another is efficient in liberating the gas. The tubes are to be heated in an oven before being used. If any material collects on the outside, it is to be removed before sealing into the X-light tube, attention being paid to having a free passage for the gas through the spun glass plugs. In Plate 137, Figure 3, is shown a cooled target tube constructed on the same design as the tube illustrated in Plate 135, Figure 1.[174] If it is desired to construct a tube with three terminals on the principle first recognized in these experiments of having the target separate from the anode -though capable of being connected with it- and nearer the cathode, the third terminal may be placed as shown by the dotted lines in Plate 135, Figure 1. For further details as to this type of tube refer to Notes 4, 16, 31. This principle has been extensively adopted by several makers of tubes, and such tubes are the most common forms now both in America and Germany.[175]

Electrical Review, December 12, 1903.

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[174] Refer to Note 1.

[175] Further experiments should be made with cathodes. Magnalium, an alloy of aluminum and magnesium, is valuable. In former notes it was said that of the common metals zinc made the best cathode. Recently Kunz and Baskerville have shown that zinc orthosilicate, zinc sulphide, zinc oxide and kunzite respond in the most pronounced manner to radium.

NOTE 176—ON THE MEDICAL USE OF SOME OTHER ETHER MOTIONS BESIDES X-LIGHT

In the Boston Medical and Surgical Journal for February 25, 1897, attention was called to a method of reducing pain and inflammation by sending a high voltage current directly through the tissues by connecting the patient with both terminals of the electric generator. Since that time the method has been in constant use, therefore it will be mentioned here, though not an X-light treatment. The procedure is painless if the terminals of the generator are of proper size for the amount of current and are in direct contact with the patient while the current is passing. In the note mentioned, a simple foot switch was recommended for starting the current after contact and stopping it before the contact was broken. This is important, as the treatment often requires to be of considerable length, making it convenient to have the patient able to control the current to save the physician's time. The experiments were made because it seemed possible electrically to produce and maintain a condition of the ether which would prevent the transmission of unwise messages by the nerves, and yet allow useful ones to be sent. In Note 30 and subsequent notes it was said an X-light tube produced not only ether waves which were X-light, but longer waves down to and below those of ordinary light. Here is pointed out the value of some of these waves in the treatment of disease. The experiments have been chiefly confined to the lower animals, but a limited experience with man has shown the value of the method in skin diseases.

The waves may be produced from vacuum tubes of the type recommended in earlier notes for therapeutics. The cathode should not bring the Varley stream to a focus, as a small area of radiant energy is not required, for definition is not sought. The cathode stream particles should strike either a broad metal target or the interior wall of the vacuum tube. The area of impact should be sufficient to prevent injurious heating, the size varying with the diseased area to be treated. The impact gives rise to ether -electro-magnetic- waves longer than those of X-light, because the velocity of the impact of the cathode stream particles is less than in an X-light tube, owing to the less exhaustion of the terminals and the greater density of the atmosphere of the tube.[175 A] This treatment is to be distinguished from that of X-light, ultra-violet light, violet light, ordinary light, heat and high-frequency waves, as the ether motions are not the same. In treating skin diseases less care is required than with X-light to avoid injury to the tissues, as the burns which can be produced are less serious and more superficial. On the other hand, the treatment may be extended to a greater depth than with Finsen light. It requires less electrical energy, for the proportion of heat waves generated is smaller, and the source of the waves can be almost in contact with the skin. Tubes for producing these waves are less expensive than X-light tubes, as the prolonged electrical treatment of the terminals is not required. The resistance of the tube should be

[175 A] Refer to Note 179 D for a description of a generator and for an illustration of a suitable tube for producing these rays, to which the name Derma Rays was given.

too low for X-light to be produced. The tubes should be given forms suited for the areas to be treated. The area from which the waves arise will be determined by the form of the cathode, which should be constructed in accordance with the results of the experiments mentioned in earlier notes. Precautions should be taken to protect the patient from other radiations, charged bodies, and electrons, when these are not wanted.

Electrical Review, December 12, 1903.

NOTE 178—ON PASSING THE BETA RADIUM RAYS THROUGH A STRONGLY CHARGED ALUMINUM PLATE

It is generally supposed that the field about a highly negatively charged plate will repel a negatively charged body, though Lenard has shown the cathode rays will pass through a thin aluminum plate connected with the earth, and Madame Curie has said the beta radium rays would do the same. The experiment to be described may therefore be interesting. It consisted in charging an aluminum plate to a potential of two hundred thousand volts and observing whether the beta rays from pure radium bromide which appeared on the side of the plate furthest from the radium could still be deflected by a magnet. Fifty milligrammes of pure radium bromide enclosed in a non-radiable capsule with a mica front were laid on the middle of a large insulated glass plate. On the capsule almost in contact with the mica front was placed a sheet of aluminum. Seven centimetres above the plate a fluorescent screen of platino-cyanide of barium was supported with its surface normal to the central ray of the beam of beta rays employed. The intensity of the illumination of the screen was observed. The aluminum was charged negatively to two hundred thousand volts. No change in the light of the screen was seen. The aluminum was charged positively to the same potential. The light from the screen appeared unchanged. The charge on the plate was reversed each second, without affecting the light. The thickness of the aluminum plate was then made nearly sufficient to absorb the beta rays, but the light on the screen was not further diminished when the plate was charged as before. The plate of aluminum was placed in series with the outer coatings of two Leydens whose inner coatings were connected with the terminals of the electric generator. Each time a spark passed between the terminals the aluminum plate was the seat of surges, but the light of the screen was apparently unchanged. In place of the plate a thin paper tray containing a layer three millimetres thick of finely divided and somewhat oxidized aluminum was used. Each flake of aluminum may be supposed to have been covered with a film which prevented metallic contact between a large number of the flakes. The theory was, — with a charged plate the charge being confined to the surface might not stop a negative charge as well as a mass of charged particles. The theory may be incorrect, and the supposition that the powdered aluminum was a mass of charged particles may be questioned. The experiments were repeated with the aluminum powder with the same results as with the plate. In the experiments the beta rays after passing through the charged aluminum were deflected by a magnet showing they had charges after passing through a field of two hundred thousand volts. How is this to be explained? The usual explanation would be to attribute the result to their enormous velocity. The following theory, which was advanced in my earlier notes for explaining the mechanism of the cathode stream, may be useful. The theory first supposes neither cathode nor beta radium rays are electrons,—electricity free from matter, as believed by some physicists,—but are charged bodies, that when electricity free from matter moves in the cathode stream or elsewhere along the lines of convection or rays, it does not move by convection, but by the interchange of partners with the polarized ether units in these lines, and when a cathode stream or other particle appears to be moving with a velocity of the order of light the thing measured has little more individual existence on its journey than the symbol we call a wave has between the source of light and the place of observation; what was measured not being an individual particle, but the movement of a strain point along the line of polarized ether units, the only free electron in the ray being the last one freed from the last link of the ether chain and becoming manifest by uniting with matter as a charge. It is probable the transportation of matter in the cathode stream—convection—is not of the order of the velocity of light as supposed by many, and we may agree with Rowland [176] who said there was no way of producing

[176] The following quotation from Rowland is given because it shows his doubt of the present theories of the cathode stream, which also have been questioned in these

this velocity in such a particle, though it fell from an infinite distance on the largest aggregation of matter in the universe. On the theory here advanced, electrons do not stream through the solar system with the velocity of light from the sun past the earth, but on the contrary there is a polarization — to use a convenient and sufficiently indefinite term — in the ether in the supposed lines of propagation, and when the effect of an electron becomes manifest it is produced as above mentioned by the last one set free in the last link of the chain. The theory would explain the apparent passage of the beta rays through highly charged aluminum by saying the charges did not get through, the charge on the particle as it approached the plate not being the same electron as the charge on the particle when it left the plate on the other side.

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notes. "A mathematical investigation always obeys the law of the conservation of knowledge: we never get more from it than we put in. The knowledge may be changed in form, it may be clearer and more exactly stated, but the total amount of the knowledge of nature given out by the investigation is the same we started with. Hence we can never predict the result in cases of velocities beyond our reach and such calculations as the velocity of the cathode rays from their electro-magnetic action has a great element of uncertainty which we should do well to remember. Indeed, when it comes to exact knowledge, the limits are far more circumscribed. How is it, then, we hear physicists stating what will happen beyond these limits? Take the velocities, for instance, such as that of a material particle moving with the velocity of light. There is no known process by which such a velocity can be obtained even though the body fell from an infinite distance on the largest aggregation of matter in the universe. If we electrify it as in the cathode rays, its properties are so changed that the matter properties are completely changed by the electro-magnetic."

Or if we choose to consider the beta radium rays as electrons, the same reasoning would apply, — the electron whose effect we observe on the far side of the charged aluminum plate is not the same one that began to propagate the effect at the radium. I am indebted to Dr. F. H. Williams for the use of some of the pure radium bromide with which he is studying the effect of the different radium rays on diseased tissues.

Electrical Review, January 9, 1904.

NOTE 179 — ON USING LIGHT OF SHORT WAVES FOR PRODUCING CHARGED PARTICLES SIMILAR TO RADIUM AND CATHODE RAYS FOR THERAPEUTIC PURPOSES

Soon after the Curies discovered radium, experiments were made on animals with a salt of radium and briefly mentioned in these notes, the radiations being recommended for treating skin diseases. These recommendations have been adopted by others, and radium has proved to have the therapeutic properties attributed to it. It is customary to consider that the alpha and beta rays of radium are charged particles. On this account and because radium is expensive a simple way of producing charged particles for use in therapeutics may be interesting. The method is new in therapeutics, though founded on an observation of Lenard, to whom also we owe the discovery of the so-called Roentgen rays. One method of applying the idea is given as an example. Place the patient on an insulated platform connected with the positive terminal of an electric generator which is producing a so-called uni-directional current of high voltage. He is then charged to a high potential. From the terminals of a source of high-voltage electricity attach wires to the sides of an enclosed portable spark-gap arranged to allow terminals of different metals to be used, the spark-gap being provided with an insulating handle to permit the source of light to be brought near any part of the patient.[176 A] Adjust the spark-gap to give the maximum amount of short ether waves. Negatively charged particles will then be sent off through an opening in the case. They can be made to impinge on any part of the patient by bringing the spark-gap into suitable position. As the particles penetrate several centimetres of air, near contact with the skin is not necessary, though as the strength of the effect varies roughly as the square of the distance, time is saved by having the distance short. One object of having terminals of different metals[177] is to take advantage of any effect from the minute particles of metal that are thrown off. This method of producing negatively charged particles is applicable to the same diseases as are the negatively charged particles from radium. It is a convenient method of treating some skin diseases, either alone or in connection to the short ether waves recommended in an earlier note[178] and called derma rays, on account of their good effect on the skin. Both of these methods have been tested on animals, and to a less extent on man, during the course of the experiments, a few of which have been mentioned in this series of notes. — Electrical Review, January 23, 1904.

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176 A Refer to Note 179 D for a figure and description.

177 Aluminum or zinc make good terminals for the production of violet and ultra-violet light, especially aluminum.

178 Refer to Note 176.

NOTE 179 A — INSULATING THE SECTIONS OF THE INTERCHANGEABLE SECONDARY TRANSFORMER DESCRIBED IN NOTES 112, 137, AND 139

In Note 112, an open circuit transformer was described in which the secondary was constructed on a new plan: the sections were not imbedded in a large mass of insulating material and attached to the tube separating the primary from the secondary, but were entirely free from this tube and from each other, thus enabling any injured section to be taken out and another inserted in a few moments even in a coil so large as to give a spark a metre long.

A very considerable number of induction coils having spark-lengths up to one metre have since been constructed on this principle by Oelling and Heinze, the Heinze Electrical Co., and by the writer. Closed circuit transformers embodying the principle have been designed by Professor Trowbridge and by the writer. As these transformers, both of the open and closed type, have been satisfactory notwithstanding adverse criticism of the method of construction, it may be worth while to describe another method of insulating a section of the secondary which is quicker and cheaper than those described and illustrated in Note 137. The two coils of a section are tied to a micanite plate, as shown in the figures in Notes 112 and 137, and in Note 179 A, Plate 138, Figure 1. Sheets of micanite -Plate 138, Figures 2 and 3- having smaller holes are laid on each side, as in Plate 138, Figure 4, the whole being put into a metal frame -Plate 138, Figure 5-. A metal disk -Plate 138, Figure 7- is then placed in the centre of the coils. The frame is converted into a deep and narrow trough, as shown in Plate 138, Figure 6, by screwing on two sides by means of bolts and thumb-nuts. Plate 138, Figure 8, is a top view of the trough with a section inside ready for pouring the ozokerite or paraffine about the coils. When the insulating material is cold, the sides of the trough are removed, the soft rubber sheet lining peeled off, and the metal frame and disk gently warmed to release the section, the excess of insulating compound being removed with a knife. As stated in Notes 112 and 137, this casting of insulating material about the coils is not necessary in this climate, though during the damp weather of August it diminishes the leakage. The coil constructed on the plan shown in Note 112 without any insulation about the coils has proved durable, being still as good as when constructed, though used with an electrolytic interrupter.[179]

Electrical Review, February 6, 1904.

NOTE 179 B—ARRANGEMENTS OF THE MULTIPLE SERIES SPARK-GAPS, CONDENSERS, SOLENOIDS AND TERTIARY COILS OF THE INTERCHANGEABLE SECONDARY INDUCTION COIL ILLUSTRATED IN NOTES 112, 140, 141

In Notes 112, 140, and 141 methods of controlling the series spark-gaps and Leydens of an inductorium for exciting X-light tubes for use in medical diagnosis were described. The object of the present note is to show further details as

[179] A simpler way is to cast a solid block of the insulating material about the two coils after they are tied to an insulating plate. In assembling the coil micanite plates are placed between the sections.

the coil has proved practical. The reader is requested to first refer to the notes mentioned. Plate 139, Figure 1, is an end view of a seventy-centimetre coil showing the arrangement of one of the two spark-gaps and condensers. The multiple series spark-gaps, one of which is shown at MSG, are operated by cords within reach of the observer while making the examination. This method of controlling the light is not, however, so good for general medical examinations as that illustrated in Notes 149, 155, 156, though particularly suited for the double target X-light tubes used in stereo-cryptoscopy, where two multiple series spark-gaps on the negative terminal afford a convenient means of adjusting the intensity of the illumination produced by the X-light from the two targets. To control a spark-gap, the observer holds a handle H in his hand, raising or lowering the rod R by means of the cord C, thus regulating the current through the X-light tube which is attached to the wire TW and to a similar one on the other terminal of the coil. The end of the regulating cord which passes over the pulley PI is always vertical over the rod R in whatever position the swinging arm SGA may be placed to bring the handle H into convenient relations with the observer while examining a patient.

The arrangements of one of the two Leydens in the secondary of the inductorium is shown in Plate 139, Figure 1. The Leyden LJ is held in the metal cup LC, and as it is not attached to the cup can easily be removed to allow one of a different capacity to be substituted. A Leyden can be thrown out of electrical connection with the inductorium by raising the arm LR to the position LR 2, shown by the dotted line. This can be done by the observer during the examination by means of a cord. Two strong uprights of insulating material support the ball CB to which is attached a rod and chain making connection with the inner coating of the Leyden. This ball and a similar one on the other end of the inductorium serve as supports for the tertiary coil mentioned in Note 112 and shown in the present note in Plate 140, Figure 2, taking the form of a single coil of wire wound on an insulating cylinder and connected at each end with the interior coating of the Leydens LJ and LJ 2, by the rods CR and CR 1, which also serve as supports. The French have for some years used solenoids in therapeutics with good results, and as their use is extending to this country, it is worth while to do what would have been a waste of effort at the time Note 112 was printed — namely, to describe in detail methods of attaching solenoids and tertiary coils to the Leyden circuits of the inductorium. The solenoid is provided with two binding posts B and B 1 for the attachment of cords leading to the patient. Outside of the solenoid may be attached a micanite tube MT about which are wrapped many turns of fine insulated copper wire enclosed in a second micanite tube MT 2, the space between being filled with a mixture of paraffine and petrolatum. The terminals of this coil are attached to binding posts TP and TP 2, from either or both of which wires may be led to the patient, the character of the discharge being modified by the length of the spark-gap in the secondary of the inductorium as well as by the capacity of the

Leydens. The currents obtained from this arrangement of a tertiary coil are of considerable value in electro-therapeutics. Further modifications of the discharge are obtained by extra spark-gaps. If the solenoid and tertiary coil are removed and wires connecting the binding posts B and B 1 and the patient inserted, his body is the seat of surgings of a similar type to those obtained from the Leyden discharges of a static machine. As these discharges from a static machine were really high-frequency currents, though called by other names, it is evident the use of high-frequency currents in electro-therapeutics is older than is usually supposed. A high-frequency current is usually considered to be one from a Tesla coil, though Henry many years ago showed all Leyden currents were of high frequency, but it was not until Tesla, amplifying the work of Hertz, published his beautiful researches that high-frequency currents were taken up by the French and developed into a valuable system of electro-therapeutics. Americans are not yet awake to their value, though instrument catalogues of recent date show one or two firms are beginning to manufacture duplicates of English copies of French apparatus made imperfectly after Tesla's ideas, instead of adopting his beautiful designs and coils with which he has produced the most wonderful electric discharges ever developed by man, — measured not by centimetres, but extending to many metres.

Electrical Review, February 6, 1904.

NOTE 179 C — ON MERCURY VAPOR IN X-LIGHT TUBES

In former papers the need of keeping mercury vapor out of X-light tubes was frequently mentioned, but the matter is of so much importance it will be made the subject of a separate note. Make an X-light tube and connect it with the mercury pump. Treat the tube until good X-light is obtained. Leave the tube on the pump with the connecting valve open for three days. Excite the tube and examine it with a spectroscope. The mercury lines will be distinctly seen. The tube will be of a less green color. There will be no X-light because there is no cathode stream, the current being carried by the mercury vapor. Make a new X-light tube. Connect it with the mercury pump. Exhaust until the resistance is equal to twenty centimetres of air. Stop the current for ten minutes to allow the resistance of the tube to rise. Start the current. The resistance will be so much higher a Geissler effect will appear in the pump, the tube becoming abnormally white. On examination with the spectroscope the mercury spectrum will be seen. Two hours' pumping may be required to produce a suitable quality of X-light. These experiments illustrate in a marked degree what frequently happens in a less degree, without the cause being known, in the routine pumping of X-light tubes. It may be said no one agent is so frequently the cause of trouble in the preparation of X-light tubes as mercury. — Electrical Review, February 6, 1904.

NOTE 179 D — ON THE CONSTRUCTION OF A TRANSFORMER FOR ETHER AND ELECTRON THERAPEUTICS

It has been repeatedly shown in earlier papers that alternating currents were not suited for exciting the primary of a transformer to be used in operating X-light tubes for use in diagnosis where a steady light and delicate adjustments were necessary, unless means of rectifying the current in the secondary were employed. The best methods will be illustrated in a future note. Unrectified currents are, however, of value in tubes for therapeutic purposes where a steady light and delicate adjustments are of less importance than the ability to use large currents for long periods without the annoyance of a break in the primary circuit. No breaks at present available are perfectly satisfactory, as they waste energy in heat and require attention. Apparatus for physicians requires to be as simple as possible. For anything in the shape of mechanism which distracts attention from the patient is objectionable. The transformer here illustrated is valuable for diagnostic work, — if a rectifier or a double-focus tube is used, — and for therapeutic purposes; especially for exciting my derma-ray tubes,[180] which when placed in a case

[180] Refer to Note 176, and for description of tubes to Notes 166 and 167. As one of my friends has recently said derma rays were X-rays, it may be well to mention a difference. When Lenard brought the cathode rays out of a vacuum tube, he found he was observing a complex radiation. Though he did not give separate names to his rays, any one who will repeat his experiments will find both X-light and derma rays. Roentgen, finding that some of Lenard's rays would show the bones, gave to these rays a specific name, — the X-rays, — and in these notes the term

with a handle, as shown in Plate 142, Figure 2, and connected with the transformer by flexible cords, are very convenient to operate and give little more trouble than an incandescent lamp. When this transformer is excited by the ordinary one hundred and ten volt, sixty-cycle street current, the current being used to light a single focus X-light tube, the same clear demarcation of the tube is seen as when it is excited by the so-called unidirectional currents from static machines. The anode line is as sharp. The tube in front of the anode is bright yellow, behind the anode blue, whichever way the tube is connected with the transformer.[181] To secure the greatest efficiency from the transformer, a special dynamo is required in which the rate of change is higher than in

derma rays has been applied to other Lenard rays which do not show the bones because they are too much absorbed by the superficial layers and too much scattered in the tissues. They penetrate black paper and pass through thin layers of glass, in these ways differing from ultra-violet light. After passing through thin glass or black paper, they will illuminate a screen of platino-cyanide barium. They are produced from a tube, whose resistance is so low the particles of the cathode stream do not strike the target with sufficient velocity to produce X-light, though X-light can be obtained from a derma-ray tube if the generator has sufficient electromotive force to drive the cathode stream particles rapidly through the dense mist of a low-resistance tube. The name derma rays was selected to distinguish these Lenard rays from others because of their good effect in skin diseases, due to their being largely absorbed by the superficial tissues which they ionize.

[181] When powerful transformers are employed in therapeutics, especially when they are used to excite vacuum tubes which are brought in contact with the body or inserted in the mouth or other cavities, insulating platforms should be used.

commercial alternating circuits. This plan of exciting an open circuit transformer has already been recommended.[182] The method is not likely to be much used at present because of the expense of the special dynamo. On this account the transformer was constructed to use the street alternating one hundred and ten volt, sixty-cycle current, or where this was not available a small commercial dynamo producing a similar current.[183] For a transformer of this type when used to produce ultra-violet light or electrons for therapeutics, the primary may have four sections each of forty-nine turns of number ten double cotton-covered copper wire. The secondary may be in thirty-eight coils, each containing nine hundred turns of number thirty-two double cotton-covered copper wire. For the method of preparing, insulating and connecting these coils refer to Notes 112, 137, 179 A, where these matters are fully illustrated in connection with open circuit transformers. The primary is arranged to use the sections in series, each section independently, or two or more in parallel. The voltage which may be obtained is always sufficient for the ultra-violet or electron arc when the transformer is excited by the current mentioned. Where a lower voltage is desired from the secondary, it may be obtained easily, as the variable potential principle illustrated and described in Notes 112, 137, and 140 is employed in the construction of the secondary. When a higher voltage is required, instead of arranging

[182] Refer to Note 159.

[183] A twelve-hundred watt dynamo giving both alternating and pulsating currents costs about one hundred and forty dollars.

the secondary and primary as in Plate 141, Figure 1, they may be equally divided on the two arms as in Plates 142, 143, 144, 146, and 147, Figures 3, 4, 5, 7, and 8. As there are two secondaries, there are double the number of turns of wire, because the number of sections is doubled. The two last forms are more suitable for exciting vacuum tubes used to produce derma rays, as the reserve of energy allows the tubes to be worked over a greater range of resistance by means of spark-gaps in series with the tube.[184] Transformers of this type are convenient for exciting the primary of a Tesla coil for use in therapeutics. Designs will be given in a future paper on Tesla coils which have been made to form part of the transformers illustrated in this note. These types of transformers are perhaps the most convenient source of ultra-violet light to be used directly or for the production of electrons, as recommended in Note 179, for ionizing the tissues in skin diseases. For these purposes the arc should be between aluminum terminals, as Lyman, who has photographed the spectrum below 1200, has found strong lines there from aluminum. For making electrons by allowing short ether waves to strike a negatively charged body -the electrons being used to ionize the molecules of skin diseases by placing a patient on an insulated platform and charging him positively as described in Note 179- the spark-gap of the transformer having aluminum terminals is mounted on an insulating handle to enable the physician to move the

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[184] Refer to Notes 6, 39, 72, 112, 160, for value of high potentials in X-light work.

source of electrons freely.[185] The arc and shield, being attached to the generator by flexible cables, allow any part of the surface of the body to be treated. The arc may be placed at the focus of a parabolic shield mounted on the same insulating handle, the shield being connected with the negative terminal of the same source of electricity whose positive terminal charges the patient. Whether the shield takes the form of a parabola, a part of a sphere or a flat surface, the physician should be protected from the energy, as already insisted on in connection with X-light, derma rays, and high-frequency discharges. Whatever form of energy is used in electro-therapeutics, it should be remembered ionization is the result to be brought about. These hinged Faraday rings are also convenient means of lighting electrodeless vacuum tubes for general therapeutical purposes. One pole of the secondary may be attached to one end of a large solenoid whose other end is connected with the vacuum tube by a flexible conductor, the inner coatings of the Leydens being united and the spark-gap in the secondary circuit made too large for a discharge to take place between the terminals, the current going back to the other terminal through the ether silently and unguided by a wire. This method is illustrated in Plate 150, Figure 13. It is useful among other

[185] When the transformer is used to develop ultra-violet light to be used directly or for the production of electrons, a large amount of irritating gas is formed by the combination of the nitrogen and oxygen of the air. A flexible rubber tube should have its open end placed near the spark, the other end being connected with an aspirator, which will remove the gas.

things for treating dilation of the stomach and pulmonary tuberculosis. During these investigations it was sometimes found desirable to combine derma rays with these electrodeless vacuum-tube treatments, as in eczema. In these cases a derma-ray tube was substituted for the ordinary electrodeless low-vacuum tube, the cathode of the derma-ray tube being attached to one pole of the solenoid in the way shown in Plate 150, Figure 13. The anode of the derma-ray tube had no metallic connection with the Faraday ring. When the derma-ray tube was brought in contact with the skin, in addition to the deeper effects obtained from an ordinary electrodeless tube, derma rays were produced for the treatment of the skin. The usual way of attaching a derma ray tube to the secondary of the Faraday ring by both terminals is illustrated in Plate 149, Figure 12. With this method the amount of derma rays produced far exceeds that yielded by the tube when only one terminal is connected, and many of the other electrical effects are too small to be considered. During these investigations a considerable number of other new electrical treatments have been used which will be described later if the matter is of sufficient interest to warrant taking the necessary time to write the descriptions and make the illustrations.

Electrical Review.

NOTE 179 E—ON LIMITING THE SPACE OF STRAINED ETHER PRODUCED BY A WIRE GUIDING AN ELECTRIC CURRENT USED IN THERAPEUTICS

When it is desirable to immerse a patient in ether which is being rapidly polarized and depolarized by means of a varying electric current, it is customary in France to place him in a solenoid. If the arms or legs are to be treated, they are placed in smaller solenoids. When a limited area of the trunk, as a shoulder, is to be treated, an encircling solenoid is not suitable, for it is unwise to subject healthy tissues to therapeutic agents. In these cases, it is best to use a principle new in therapeutics, -that of limiting the disturbance in the ether by surrounding the wire,- which may be in the form of a flat or extended spiral, either straight or flaring, — with a metal surface, the metal shield having an opening toward the area to be treated. A number of such devices should be on hand to suit different cases. No figures are given, as the object of the note is to call attention to a principle which is of considerable value in therapeutics and not to illustrate special forms of apparatus. In earlier notes the importance of limiting the direction of escape of X-light, derma rays, and of the energy from the radio-active bodies was insisted on, and this note is written to extend the principle to other agents used in electro-therapeutics. — Electrical Review.

NOTE 179 F — ON AN ARRANGEMENT OF A MECHANICAL PUMP FOR EXHAUSTING VACUUM TUBES FOR USE IN MEDICINE

In earlier notes the only pumps illustrated used mercury because they could be made for a few dollars by experimenters. As mercury pumps may introduce mercury vapor[186] into

[186] In his experiments with radium bromide, Curie used two U-tubes cooled by liquid air to prevent mercury vapor

vacuum tubes, where its presence is objectionable, an arrangement of a mechanical pump in connection with a cooling closet for the pump and hot closet for the tube is now illustrated, notwithstanding the great cost of the mechanical pump, because for low vacua the exhaustion is more rapid than with a mercury pump. The same precautions must be used to keep water vapor out of the pump when standing unused as have been recommended in earlier papers in connection with mercury pumps. Therefore a glass tube should be attached to the mechanical pump by a ground joint, instead of by a rubber tube, the joint being provided with a cup which when filled with oil will act as a seal. The other end of the tube should have a stopcock which must always be closed before the X-light tube is removed from the pump. Above the stopcock there should be a second similar ground joint for connecting the X-light tube. The same precautions recommended earlier for removing most of the air and water vapor from the vacuum tube by a hand pump before it is connected with the mechanical pump should be employed. The mechanical pump should be in a closet similar to those already shown in connection with mercury pumps, and illustrated in Plate 151, Figure 1, provision being made for inserting ice to lower the temperature during hot weather to reduce the tendency of oil vapor to enter the vacuum tube. Oil vapor

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from entering the tube. Whenever liquid air becomes available, X-light tubes, in which high vacua are needed, should be exhausted with a mercury pump arranged in this way, as no mechanical pump tested during these experiments was found practical for producing a high vacuum.

is less objectionable than mercury, for by raising the temperature of the tube oven it may be burnt out as directed in earlier notes, which should be consulted.

NOTE 179 G—FURTHER EXPERIENCE IN REGENERATING X-LIGHT TUBES BY INTRODUCING HYDROGEN BETWEEN THE MOLECULES OF A PALLADIUM TUBE FORMING PART OF THE WALL OF THE X-LIGHT TUBE

After deciding to reprint some of these papers it seemed worth while to add another note on regenerators. The hydrogen theory stated in these notes may not be accepted; but the experience gained during the last seven years in using palladium as an intermolecular hydrogen regenerator for X-light tubes has proved the method to be valuable, therefore attention is again called to it by an appeal to the eyes through the illustration on Plate 152. If the only proof that hydrogen was introduced in this way depended on the statements made in these papers it might be considered insufficient, but fortunately the method was brought to the attention of Professor Trowbridge, who used it in some of his investigations on hydrogen, which are the most extensive that have been made. Trowbridge found hydrogen was introduced. The only objection to my intermolecular regenerators has been the difficulty in making them. Seamless palladium tubing can now be obtained, therefore the construction of the regenerators presents no difficulty. In addition to a regenerator every X-light tube which is to be excited by a powerful coil requires an automatic regulator to lower the starting resistance and maintain the working resistance at the proper point to insure the X-light being of the desired quality. This has been frequently described and illustrated in earlier notes. It is again mentioned because many tubes are made without automatic regulators or with complicated and unsatisfactory forms. The palladium regenerator shown in Plate 152 is a thin palladium tube closed at the outer end and sealed into the X-light tube at the open end. The regenerator may be operated by heat or electrolytically, to store the palladium with hydrogen. As shown in the illustration, its supporting glass tube is used for the attachment of one part of the automatic regulator. In using the automatic regulator the spark-gap SG is made of the desired length, seven millimetres, for example. The current which cannot pass between the terminals of the X-light tube, on account of its initial high resistance, goes through the wire RW to the wire SWG, jumps through the ether of the spark-gap SG to the movable wire MW, then through the automatic regulator bulb B to the stem TS back to the electric generator, liberating water vapor from the chemical in the regulator bulb, which lowers the resistance of the X-light until a normal cathode stream can form, when the vapor is reabsorbed to be given off again if the resistance to the continuation of the cathode stream becomes too great.

NOTE 179 H — ON X-LIGHT BATHS

In earlier notes the importance of studying the effects of X-light on internal diseases was pointed out. Experiments on animals were described which showed when the proper kind of X-light was used, the source being at the right distance, profound internal effects could be produced without burning the skin. In taking advantage of the powerful ionization which X-light produces on internal tissues during attempts to treat internal tuberculosis and cancer, the patient should be immersed in an X-light bath, as was done with the guinea pigs -used in some of these experiments-, for not only the chief apparent seat of the disease may require treatment, but also smaller unknown and scattered areas. A special diaphragm plate is required for the X-light tube box. In this case the metal forming the diaphragm plate, instead of being non-radiable, should be somewhat radiable. The beam of X-light which passes unimpeded through the opening of the diaphragm is adjusted to cover the apparently diseased area, while at the same time the surrounding tissues, which may be the whole or a part of the body outside this area, are bathed in X-light of less intensity coming through the radiable metal of the diaphragm plate. The patient should be placed on the revolving platform shown in Note 162 and turned during the exposure, as this diminishes relatively the duration of the exposure of any part of the skin. These X-light baths have been extensively used during these experiments on guinea pigs, and have been found practical on man.

NOTE 179 I — A GROUPING OF SOME OF THE AXIOMS MENTIONED

In an X-light tube the space enclosed by the glass walls should vary directly with the rate of using electrical energy in the tube.

In an X-light tube the size of the cathode should vary directly with the rate of discharging electricity from its face, and with the size of the surges.

In an X-light tube the target should be cooled when it is struck by a powerful cathode discharge.

In an X-light tube the target should be placed at the focus of the cathode discharge.

In an X-light tube the distance between the cathode and the target should be capable of variation, or there should be an automatic regulator.

In pumping X-light tubes the X-light should not strike the observer.

In pumping X-light tubes they should be enclosed in a non-radiable oven.

In pumping X-light tubes water vapor should be excluded from the pump.

In pumping X-light tubes mercury should be kept out of the tube.

In pumping X-light tubes the removal of the gases is but a part of the work, the value of the tube depending also on the electrical treatment of the terminals.

In pumping X-light tubes they should be hot, and the pump should be warm, if a mercury pump.

In pumping X-light tubes the necessary amount of gases should be removed from the glass and the interior of the tube before they are electrically taken from the terminals.

In pumping X-light tubes the absence of leaks should be insured before the electrical treatment of the terminals begins.

In pumping X-light tubes the amount of electrical energy to be afterward used with the tube should be known, the terminals being treated to bear that amount.

In using X-light the source should be in a non-radiable tube box from which no X-light can escape except the smallest beam which will serve the purpose.

In using X-light it should not strike the observer.

In using X-light selective filters should be employed to strain out undesirable radiations.

In using X-light the fluorescent screen should be covered on the side toward the observer with a plate of heavy lead glass as a protection from the X-light.

In using X-light with a cryptoscope the walls of the instrument should be non-radiable to prevent the entrance of X-light except in the direct beam.

In using X-light with a fluorescent screen, whether open or enclosed in a cryptoscope, the surface of the screen should be held normal to the central ray of X-light employed.

In making photographs by X-light, only the beam arising from the radiant area of the target should be allowed to strike the photographic plate.

In making photographs by X-light the central ray of the beam of X-light employed should strike the photographic plate normal to its surface.

In making photographs by X-light the place where the central ray of the beam employed strikes the plate should be automatically recorded on the negative.

In making photographs by X-light the position and distance of the source of X-light should be automatically recorded on the negative.

In making photographs by X-light the object being photographed should be enveloped in a non-radiable covering which will admit only the X-light in the direct beam employed.

In using X-light in medicine the examination room should be fumigated every night.

In using X-light in medicine the apparatus should be sterile.

In using X-light in medicine none should strike the patient except the smallest beam which will cover the area to be examined, photographed or treated.

In using X-light in diagnosis, to avoid undue exposure of the patient, the X-light should be produced in surges, each of the shortest possible duration, with as long periods between as are compatible with a light apparently steady, advantage being taken of the persistence of vision and of luminescence. The more luminescent the salt of the fluorescent screen, the shorter the surges may and should be, with moving organs like the heart and lungs.

In using X-light in medicine, the physician should be able to make all the adjustments of the light without removing his eyes from the image on the fluorescent screen.

In using X-light in medicine, the physician should be able to orient in relation to the patient and the source of X-light at all times during an examination without removing his eyes from the image on the fluorescent screen.

In using X-light in therapeutics, its waves should be such as are most absorbed by the diseased tissues.

In using X-light in therapeutics, the waves should be as long as can be employed without injury to the overlying tissues.

In using X-light in therapeutics, the distance of its source from the surface of the body through which the X-light enters should vary directly [187] with the distance of the diseased tissue below that surface.

In using X-light in therapeutics the distance of the diseased tissues below the surface of the body through which the X-light enters should determine the form of vacuum tube to be employed.

In using X-light in therapeutics the nearer the diseased tissue is to the surface of the body through which the X-light enters, the nearer the source of X-light should be to the nearest wall of the vacuum tube.

In using X-light in treating diseases of the outer surface of the body, the X-light tube should be in a portable non-radiable case from which no X-light can escape except toward the diseased tissues, the tube box being provided with a handle to allow the tube to be moved over the diseased area.

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[187] Directly is used as the opposite of inversely and to mean that the further the disease is below the surface, the further the source of X-light should be above the surface. It is used broadly and does not imply if the disease is a certain distance below the surface, the source of X-light should be an equal distance above the surface. Refer to earlier notes for details. The following is a more general statement. In using in therapeutics radiations which have the power to pass through the body, the distance of their source from the surface of the body through which the radiations enter should vary directly with the distance of the diseased tissue below that surface when the radiations vary in intensity approximately as the square of the distance, — the further the disease is below the surface, the further above the surface should be the source of the radiations.

In using X-light in treating diseases of the outer surface of the body, the source of X-light should be at the wall of the vacuum tube.

In using X-light in treating diseases of the outer surface of the body, the area to be treated should determine the area of the tube wall from which X-light should originate.

In using X-light in treating diseases of the outer surface of the body where the vacuum tube is brought in contact with the skin, the area of the wall of the tube from which X-light arises should be cooled.

In using radio-activity, the source of the energy should be in a case from which no radio-activity can escape except in the required direction.

In using radio-activity, the investigator should be protected from the energy.

In using radio-activity in medicine, the beam of energy striking the patient should be the smallest which will cover the area to be examined, photographed or treated. In using radio-activity in medicine, the distance of the source of energy from the surface of the body through which the energy must pass should vary directly with the distance of the diseased tissue below that surface; the nearer the disease to the surface, the nearer the source of energy should be to the surface.

Electrical Review, December 12, 1903.

NOTE 180—WHY SHOULD SUCH DISSIMILAR AGENTS AS ETHER WAVES AND CHARGED PARTICLES SHOW SIMILAR CURATIVE POWERS?

It is generally known that X-light, usually supposed to be a motion of the ether, has therapeutic properties. It is less well known, though proved by experiment, that other ether waves originating in a vacuum tube and called derma rays have similar properties.[188] It is generally known that radium, which gives off charged particles, has therapeutic properties. It is less known, though proved by experiment, that charged particles given off from a negatively charged body illuminated by ultra-violet light have similar properties.[189] At present ether waves and charged particles appear dissimilar. When similar results are produced by dissimilar agents the philosophical mind seeks the reason. In the case of the similar therapeutic properties of ether waves and charged particles the results are due to a power possessed in common of producing ions. When the molecules of the human body are ionized or broken, the results are similar though the active agents are unlike. This theory, which has been used in experiments some of which have been mentioned in these notes, applies also to therapeutic results obtained from longer ether waves and charged particles from other sources in general use in electro-therapeutics, and therefore is a useful generalization to be used in investigation, and in therapeutics. — Electrical Review, February 6, 1904.

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[188] Refer to Notes 176 and 179 D.

[189] Refer to Note 179.

NOTE 181—ON USING RADIO-ACTIVE SUBSTANCES IN X-LIGHT AND DERMA RAY TUBES

In Note 115, Electrical Review, February 2, 1901, an X-light tube with a radio-active cathode was described and illustrated, the radio-active substance — impure radium chloride — forming the face of the cathode. In another experiment the radio-active substance was placed in a receptacle and covered with a thin plate of aluminum forming the concave side of the cathode. The object of the experiments was to see if the life of the cathode stream could be prolonged by any properties of the radio-active substances; for use increases the resistance of a vacuum tube until the cathode stream does not form.

To overcome the resistance, hydrogen has been recommended, and various methods of operating a hydrogen regulator have been given, the best perhaps being the introduction of the gas through the intermolecular spaces of a palladium tube forming part of the wall of the vacuum tube. Regulators of this kind have been shown in Note 50, Figure 52, Electrical Review, February 15, 1899; Note 62, Figure 57, Electrical Review, April 26, 1899; Note 86, Figure 68, Electrical Review, February 7, 1900. Instead of hydrogen, radio-active substances were employed, as they continually produce hydrogen as well as helium. The radio-active substance used in most of the experiments was radium chloride of an activity three thousand times that of uranium. It was placed in a small tube attached to the X-light tube and held in place with a plug of glass wool. If the rate at which the gas is liberated from the radio-active substance is not rapid enough to keep down the resistance of the X-light tube, a more rapid escape can be produced by heating. The most practical arrangement for producing this sudden liberation was a modification of the plan described in Note 138, Electrical Review, May 3, 1902. The radio-active material was mixed with a conducting powder and packed in a tube as shown at HR, Figure 2, Electrical Review, December 12, 1903. This tube was placed in shunt circuit allowing the generator used to excite the X-light or derma ray tube to produce at will the necessary heat in the radio-active substance to liberate sufficient material to cause the cathode stream to start, the current then being automatically shut off to prevent the rapid liberation of more material. Rutherford having shown that his emanation gave rise to the excited activity discovered by the Curies, and that the excited activity could be condensed on a negatively charged wire instead of being indiscriminately deposited on all surrounding substances, — the wire reaching an activity ten thousand times as great as the thoria from which the emanation arose, — experiments were tried in which the cathodes of the X-light tubes containing the radio-active substances were kept charged negatively when the tubes were not in use, to see if the condensation on the cathodes could prolong the life of the cathode stream. Now that radio-active substances of considerable intensity are easily obtainable, these methods are of interest.

Electrical Review, July 30, 1904.

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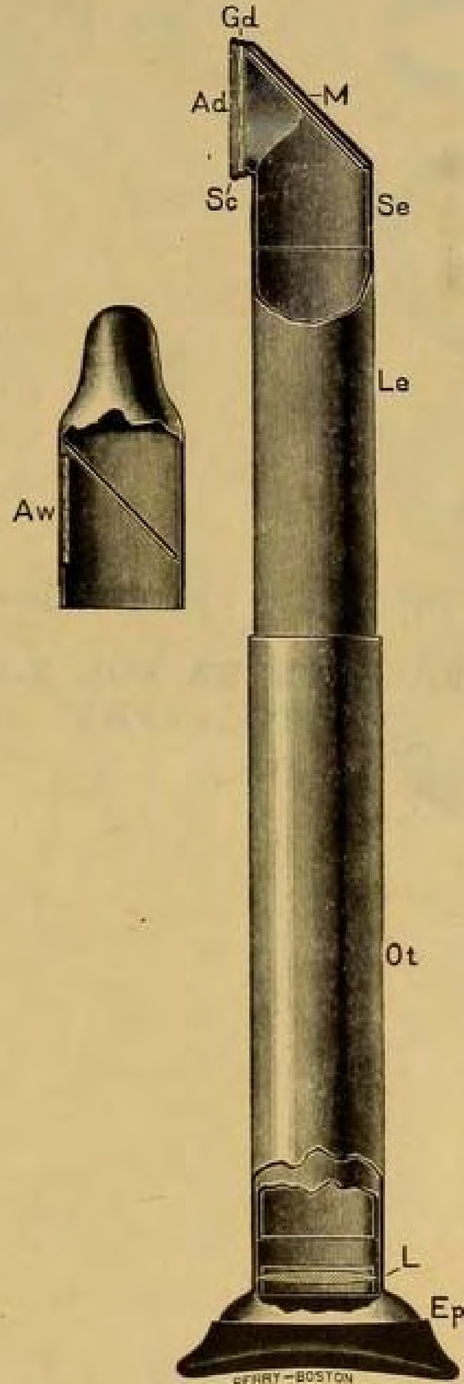
ILLUSTRATIONS

NOTE B — FIGURE I — A REFLECTING CRYPTOSCOPE AND CRYPTOSCOPIC CAMERA WITH NON-RADIABLE WALLS


Gd
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PERRY—BOSTON

NOTE C — FIGURE 1 NOTE C — FIGURE 3

AN ORAL CAMERA FOR X-LIGHT PHOTOGRAPHY

Figure 1

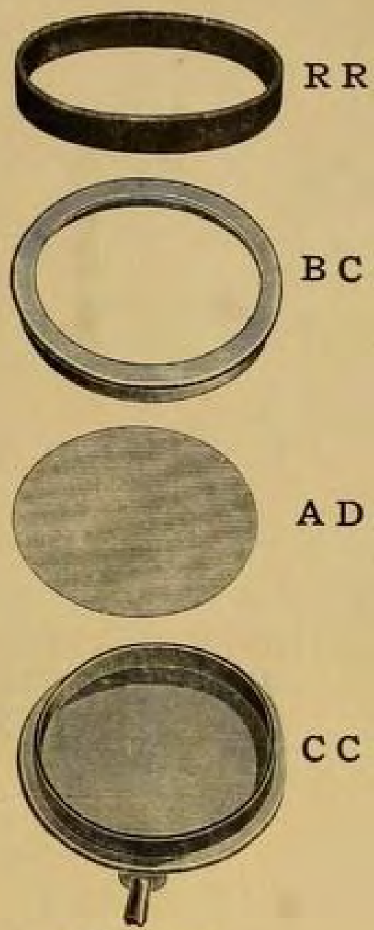
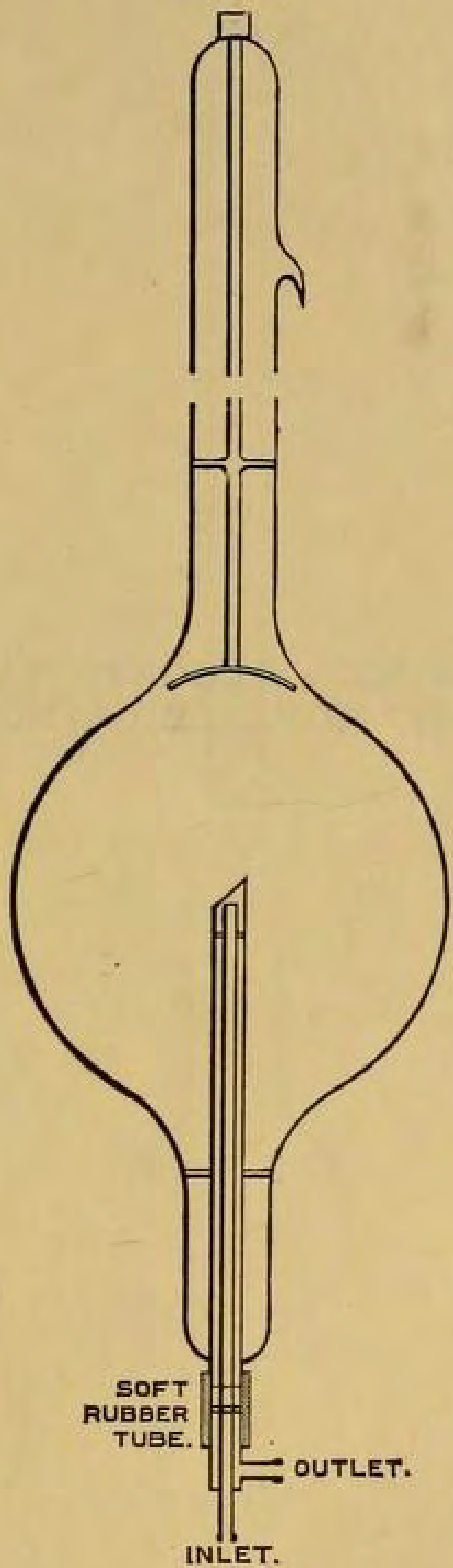
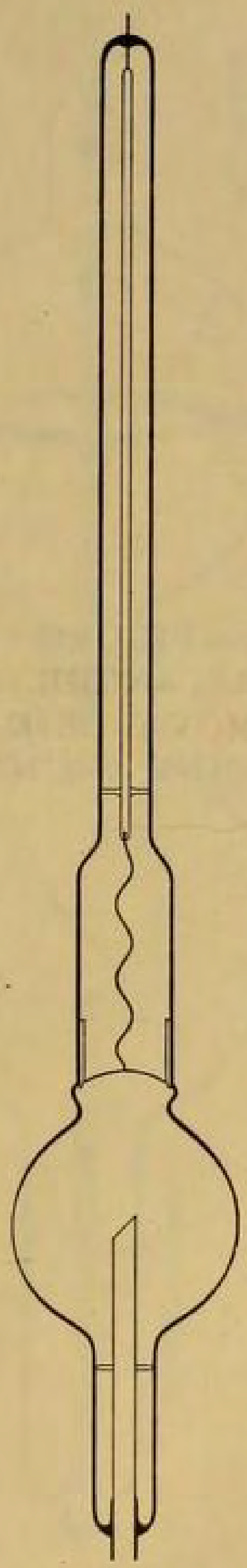


Figure 3

NOTE I — FIGURE I — COOLED TARGET
X-LIGHT TUBE

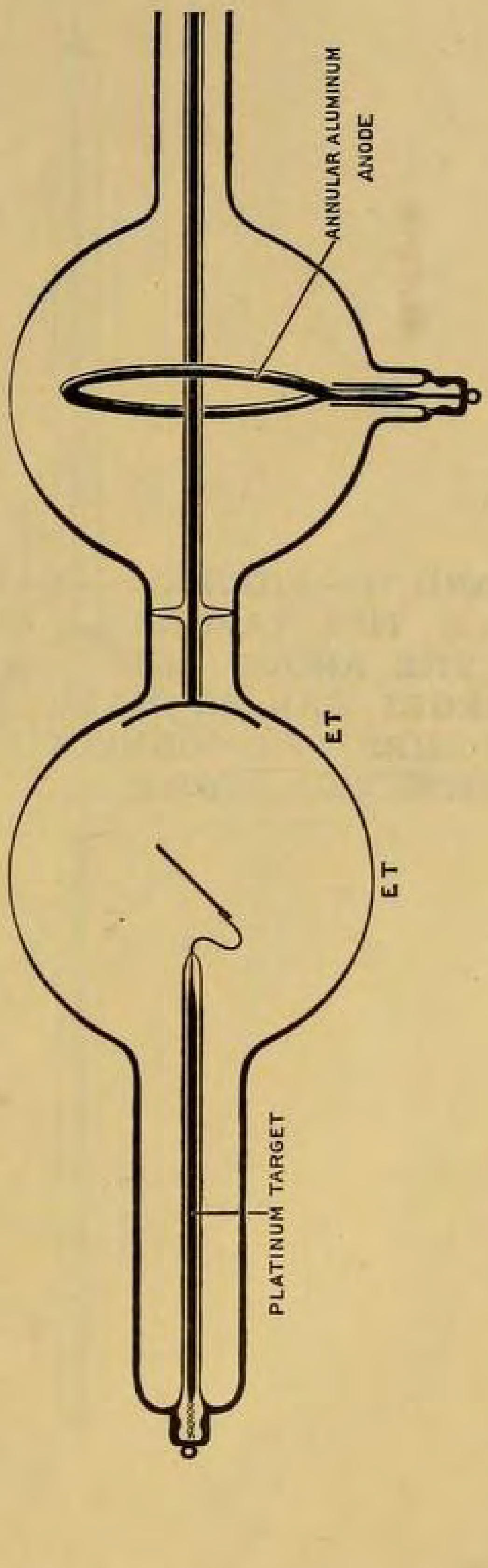

SOFT
RUBBER
TUBE.
OUTLET.
INLET.

NOTE 4—FIGURE 4—COOLED TARGET TUBE, WITH MOVABLE CATHODE

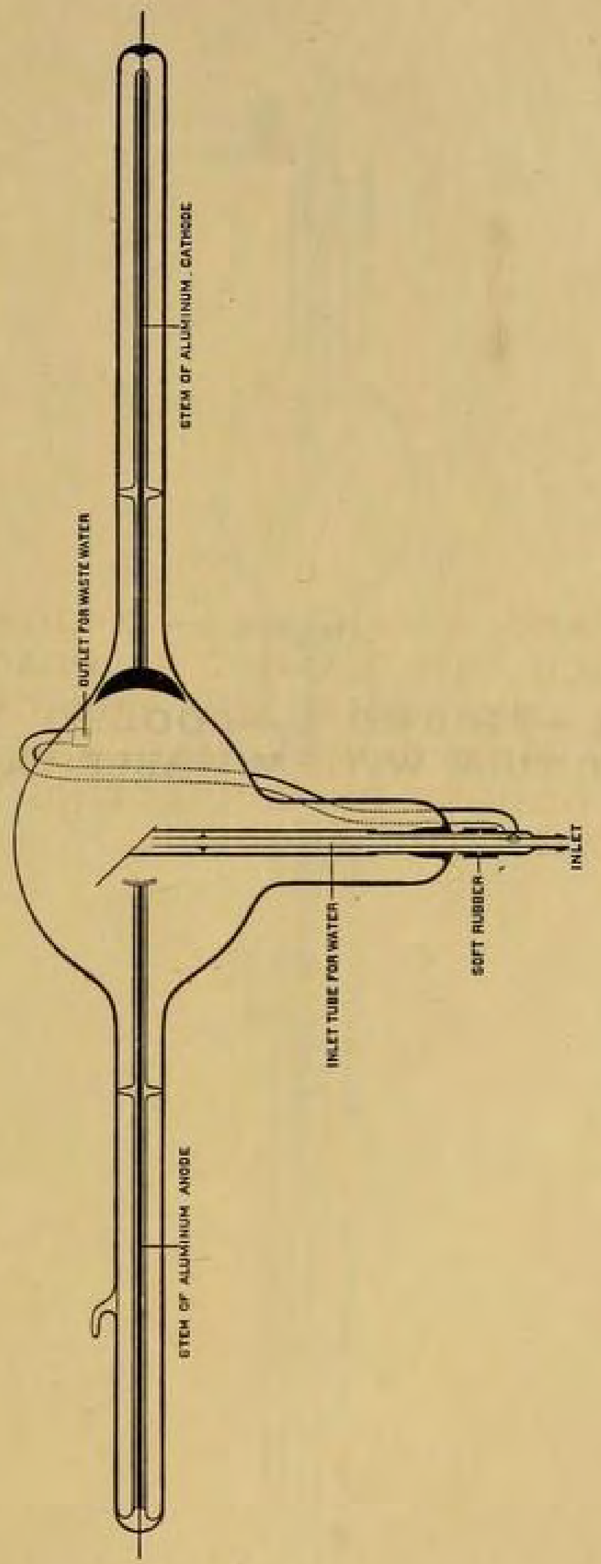


NOTES 15 AND 16 — FIGURE 1 — X-LIGHT TUBE, WITH ANNULAR ANODE, TO SHOW THAT THE POSITION OF THE ANODE DETERMINES THE POINT FROM WHICH X-LIGHT WILL ARISE

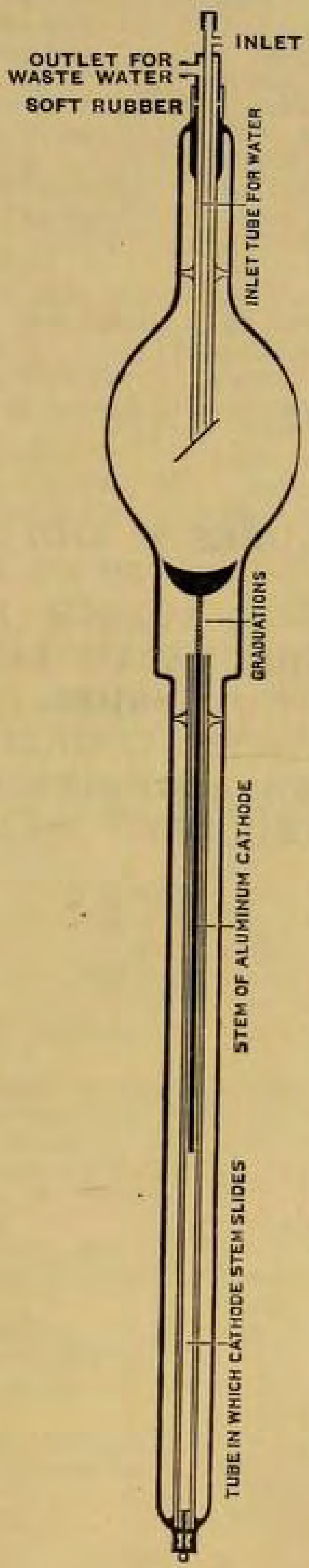
Plate 5



NOTES 16 AND 17 — FIGURE 2 — X-LIGHT TUBE IN WHICH THE TARGET IS PLACED BETWEEN THE ANODE AND THE CATHODE. THE TARGET CAN BE MADE AN ANODE, WHEN DESIRED, BY CONNECTING IT BY A WIRE WITH THE ANODE


STEM OF ALUMINUM CATHODE
OUTLET FOR WASTE WATER
INLET TUBE FOR WATER
SOFT RUBBER
INLET
STEM OF ALUMINUM ANODE

NOTE 19—FIGURE C—COOLED TARGET X-LIGHT TUBE WITH MOVABLE CATHODE


INLET
OUTLET FOR WASTE WATER
SOFT RUBBER
INLET TUBE FOR WATER
GRADUATIONS
STEM OF ALUMINUM CATHODE
TUBE IN WHICH CATHODE STEM SLIDES

FIGURES D AND D 1

NOTE 19 — DIRECT ACTING X-LIGHT TUBES WITH DIAPHRAGMS TO LIMIT THE RADIANT AREAS TO INSURE SHARP DEFINITION, AND WITH COOLED TARGETS TO ALLOW LARGE AMOUNTS OF ENERGY TO BE CONVERTED INTO X-LIGHT

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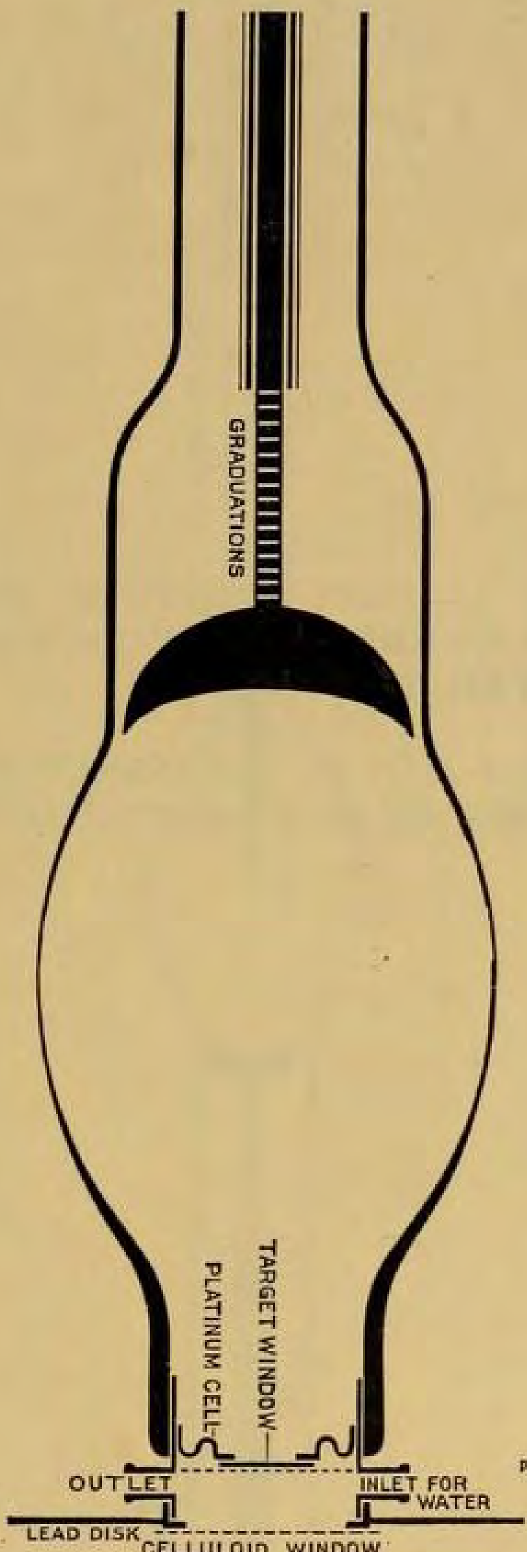


Figure D

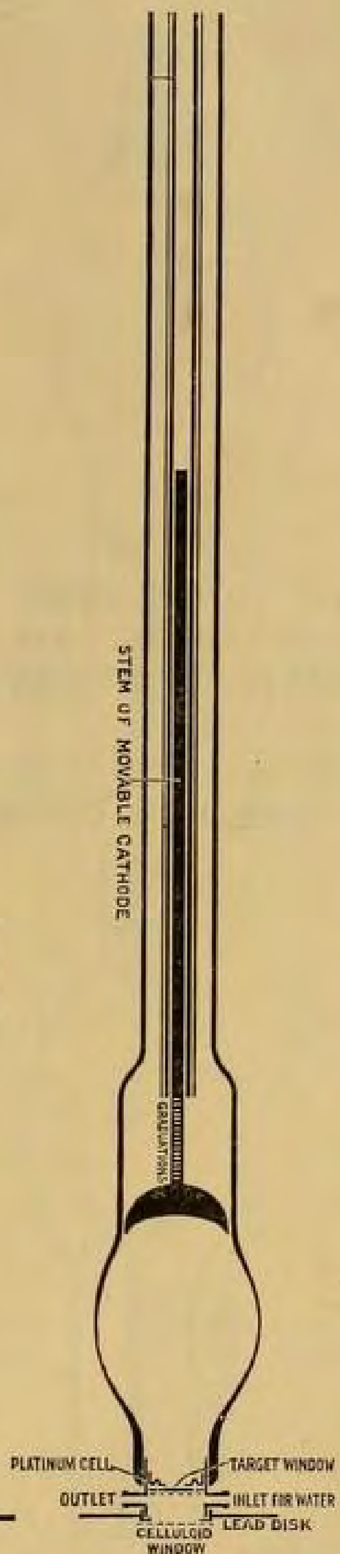


Figure D 1

NOTE 20 — FIGURE 5 — BEST POSITION FOR A CATHODE. AN X-LIGHT TUBE WITH MAGNETICALLY MOVED TERMINALS

NOTE 20 — FIGURES 6 AND 7 — INCORRECT POSITIONS FOR CATHODES IN X-LIGHT TUBES

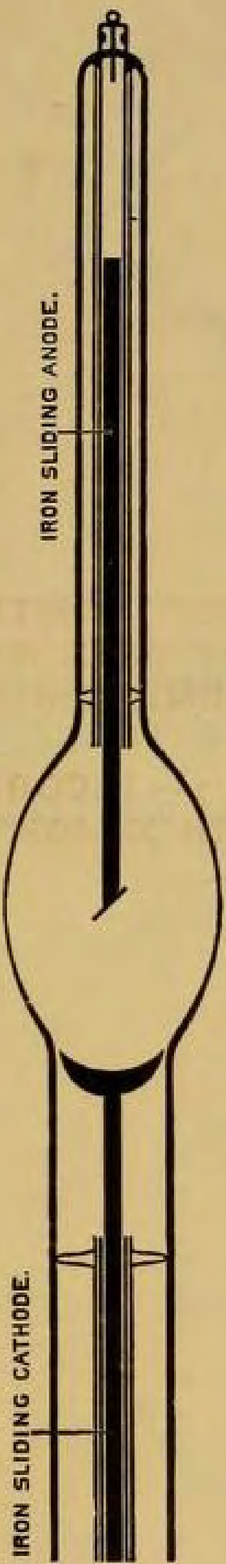


Figure 5

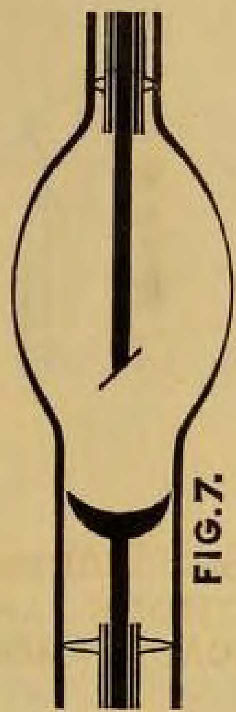


FIG. 7.

FIG. 6.

NOTE 21 — FIGURES 8 AND 9 — UNCOOLED ANODES IN REFLECTING FOCUS TUBES

NOTE 22 — FIGURE 10 — DR. WILLIAMS' TUBE

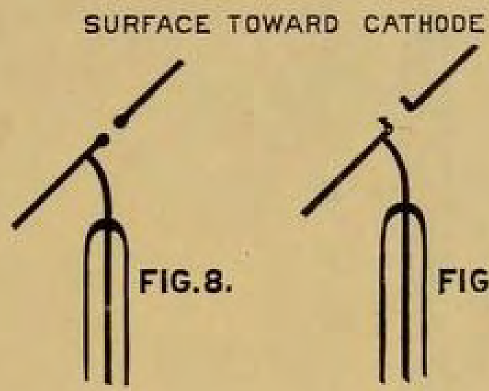


FIG. 8. FIG. 9.

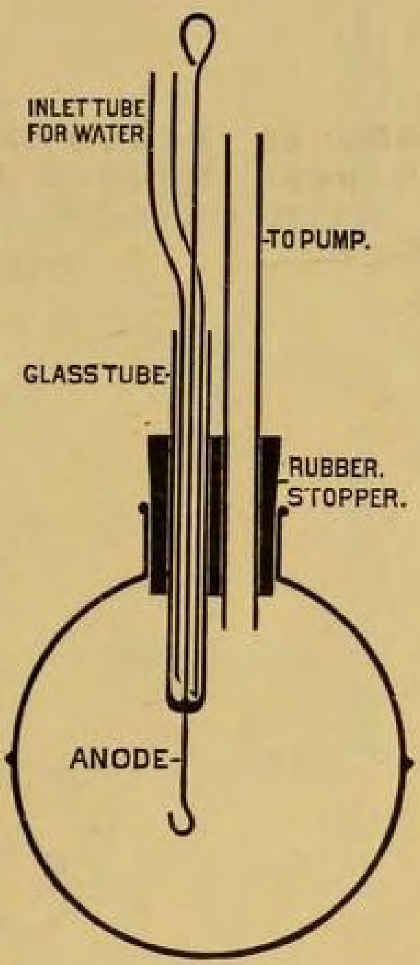


Figure 10

NOTES 30 AND 33 — FIGURES 30 AND 31 — COOLED TARGET X-LIGHT TUBE REGENERATING WITH OXYGEN — PERFORATED CATHODE

Figure 31

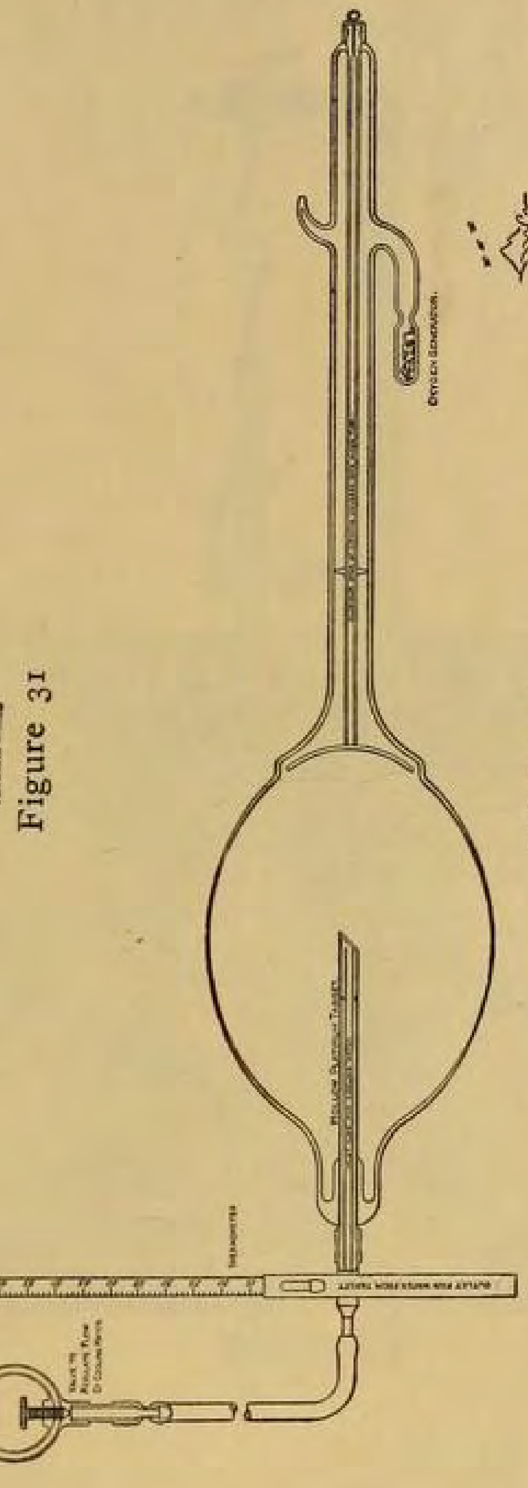
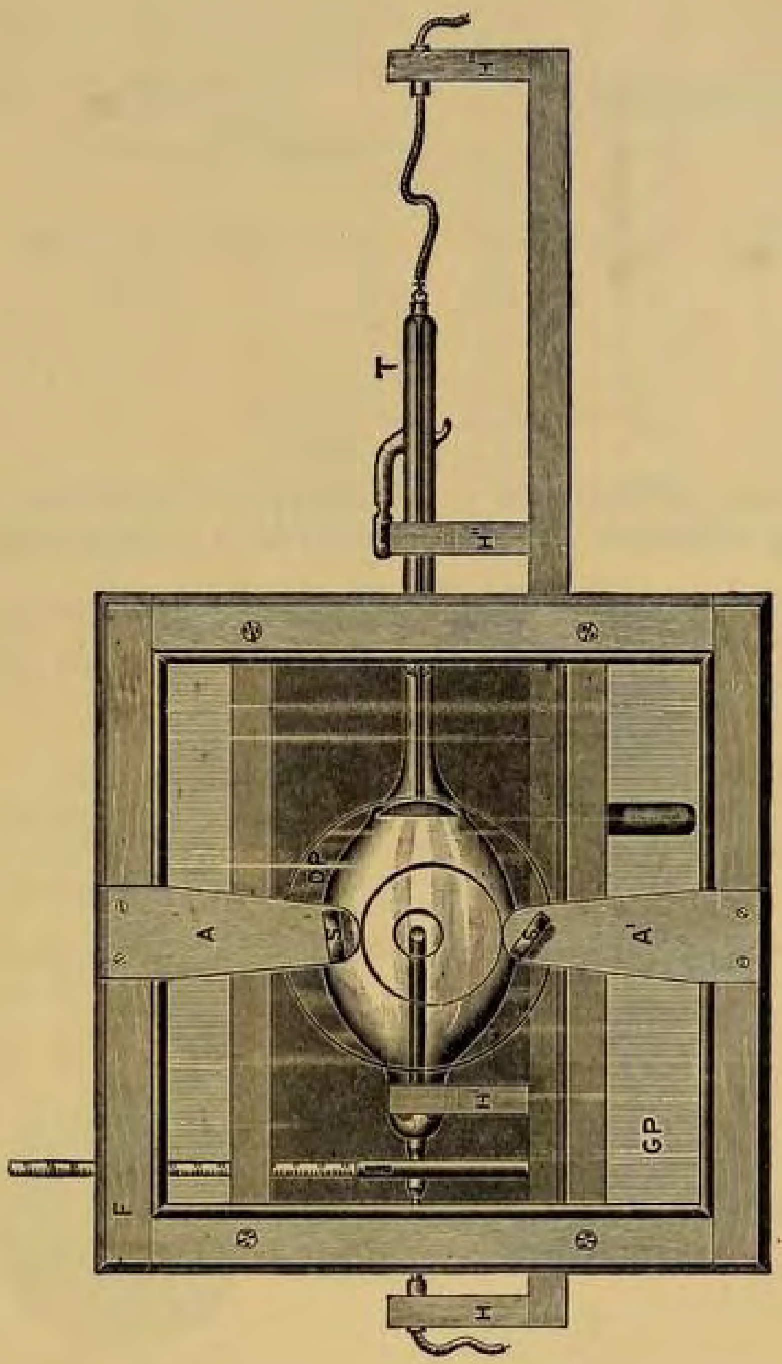


Figure 30

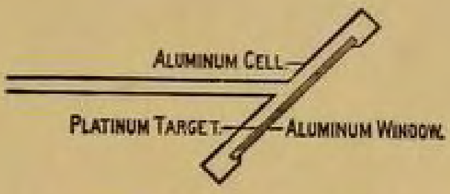
NOTE 36—FIGURE 34—NON-RADIABLE X-LIGHT TUBE BOX WITH CENTRING DIAPHRAGM PLATE


H
T
H'
A
A'
H
GP
F
H

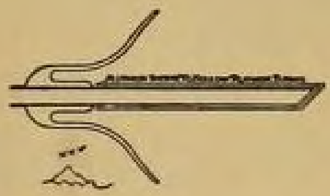
NOTE 35 — FIGURES 32 AND 33 — COVERING THE PLATINUM TARGET WITH ALUMINUM

NOTE 36 — FIGURES 35, 36, AND 37 — DIFFERENT POSITIONS FOR THE NON-RADIABLE TUBE BOX SHOWN IN PLATE 12

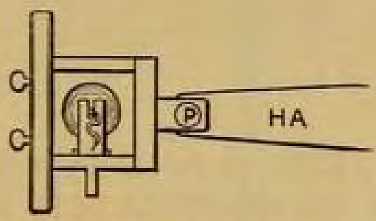
NOTE 37 — FIGURE 38A — COOLING THE TARGET OF AN X-LIGHT TUBE WITH EXTERNAL METAL VANES



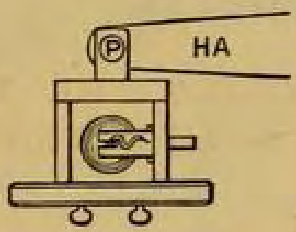
Note 35 — Figure 32



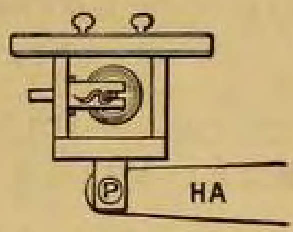
Note 35 — Figure 33



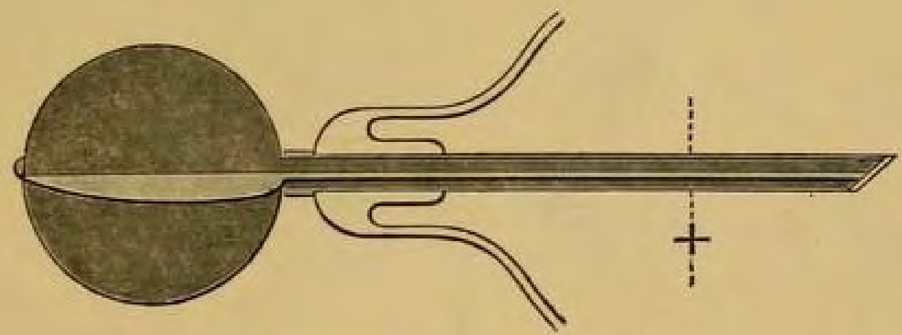
Note 36 — Figure 35



Note 36 — Figure 36

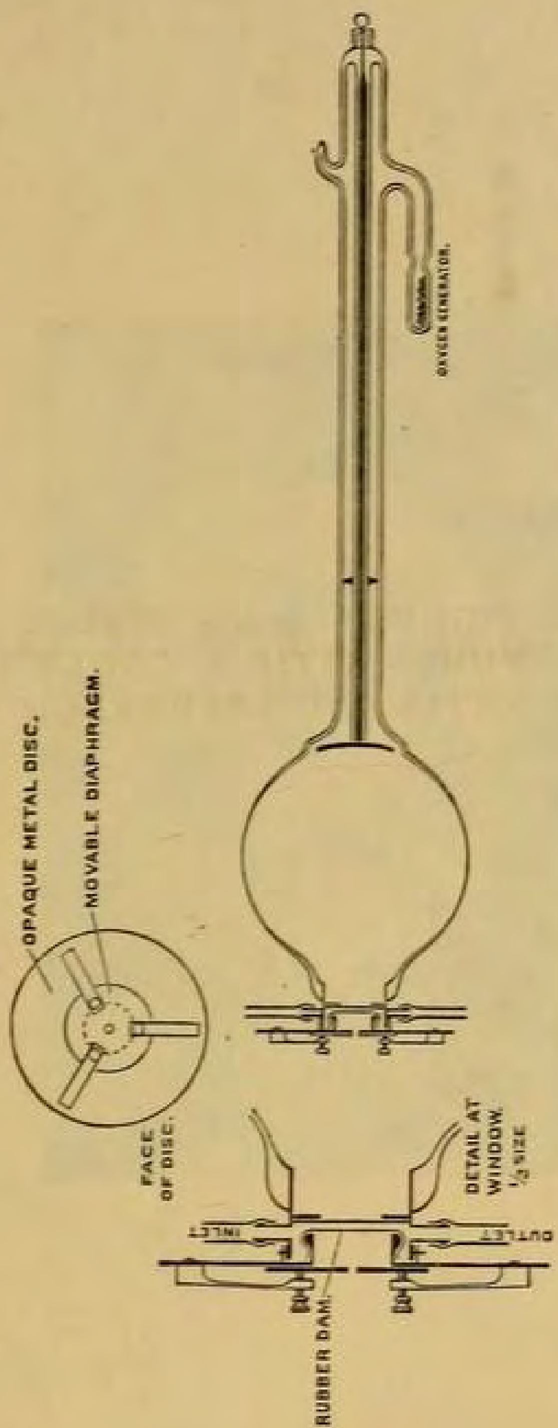


Note 36 — Figure 37

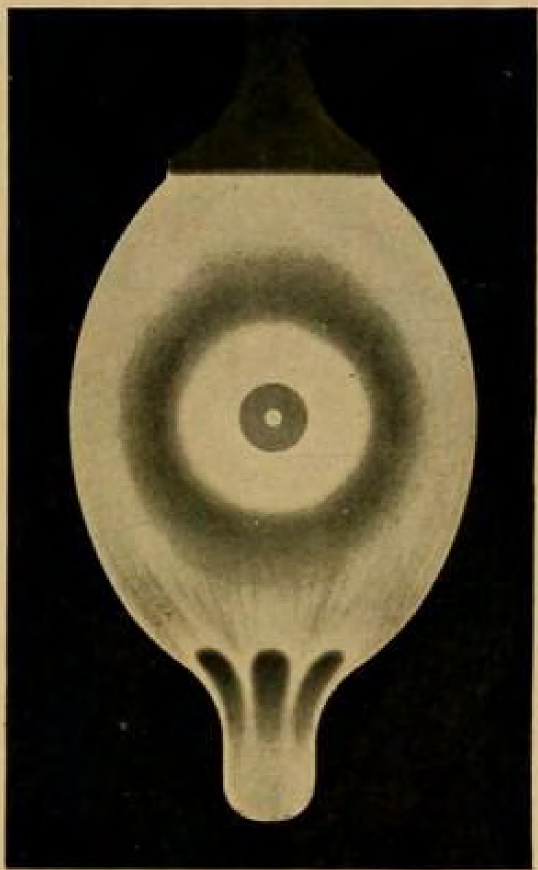


Note 37 — Figure 38 A

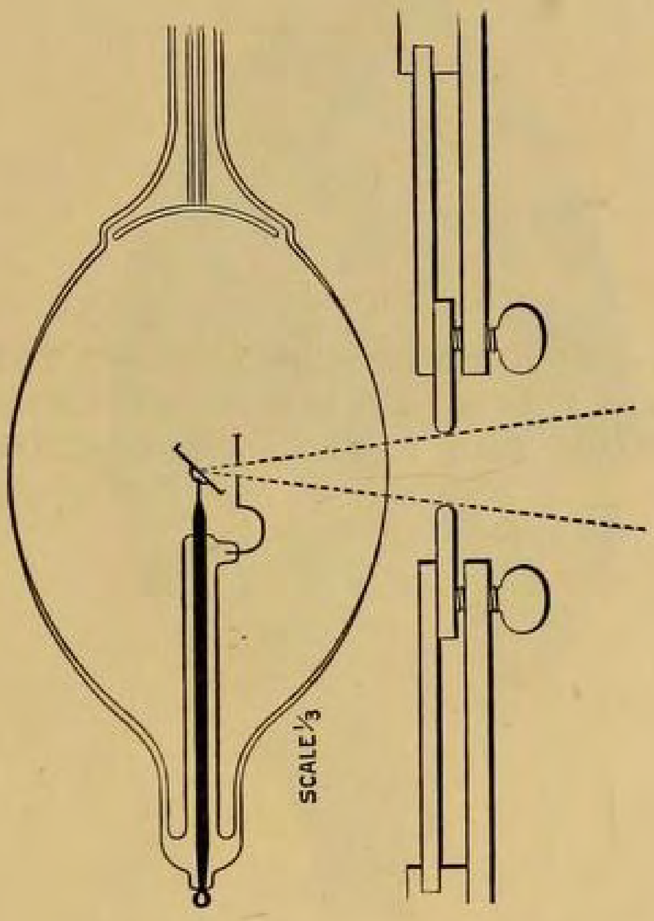
NOTE 41—FIGURE 41 A—DIRECT ACTING X-LIGHT TUBE, WITH A COOLED TARGET AND AN EXTERNAL DIAPHRAGM


OXYGEN GENERATOR.
OPAQUE METAL DISC.
MOVABLE DIAPHRAGM.
FACE OF DISC.
DETAIL AT WINDOW 1/3 SIZE
INLET
OUTLET
RUBBER DAM.

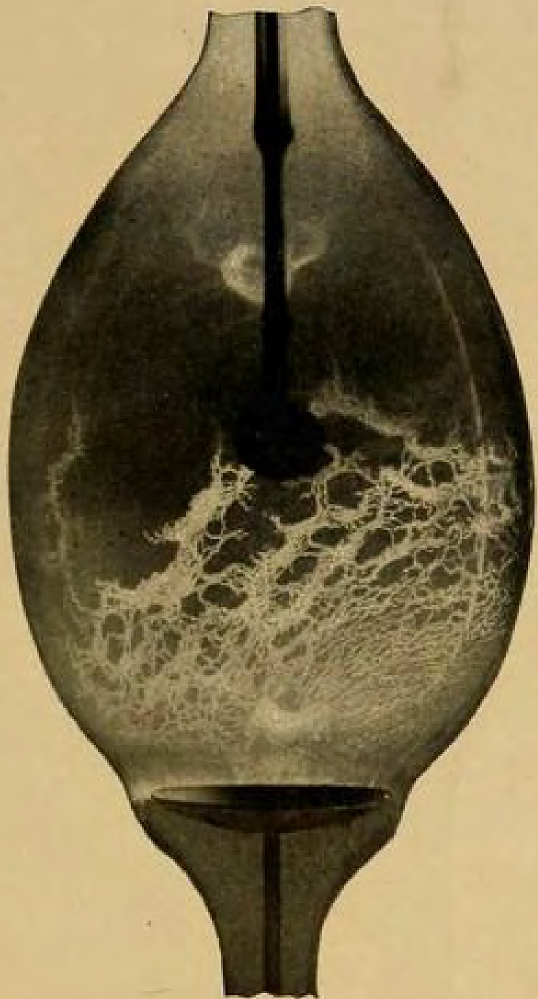
NOTE 45 — FIGURE 43 — INTERNAL DIAPHRAGM X-LIGHT TUBE EXCITED



NOTE 45 A — FIGURE 42 — INTERNAL DIAPHRAGM X-LIGHT TUBE


SCALE 1/3

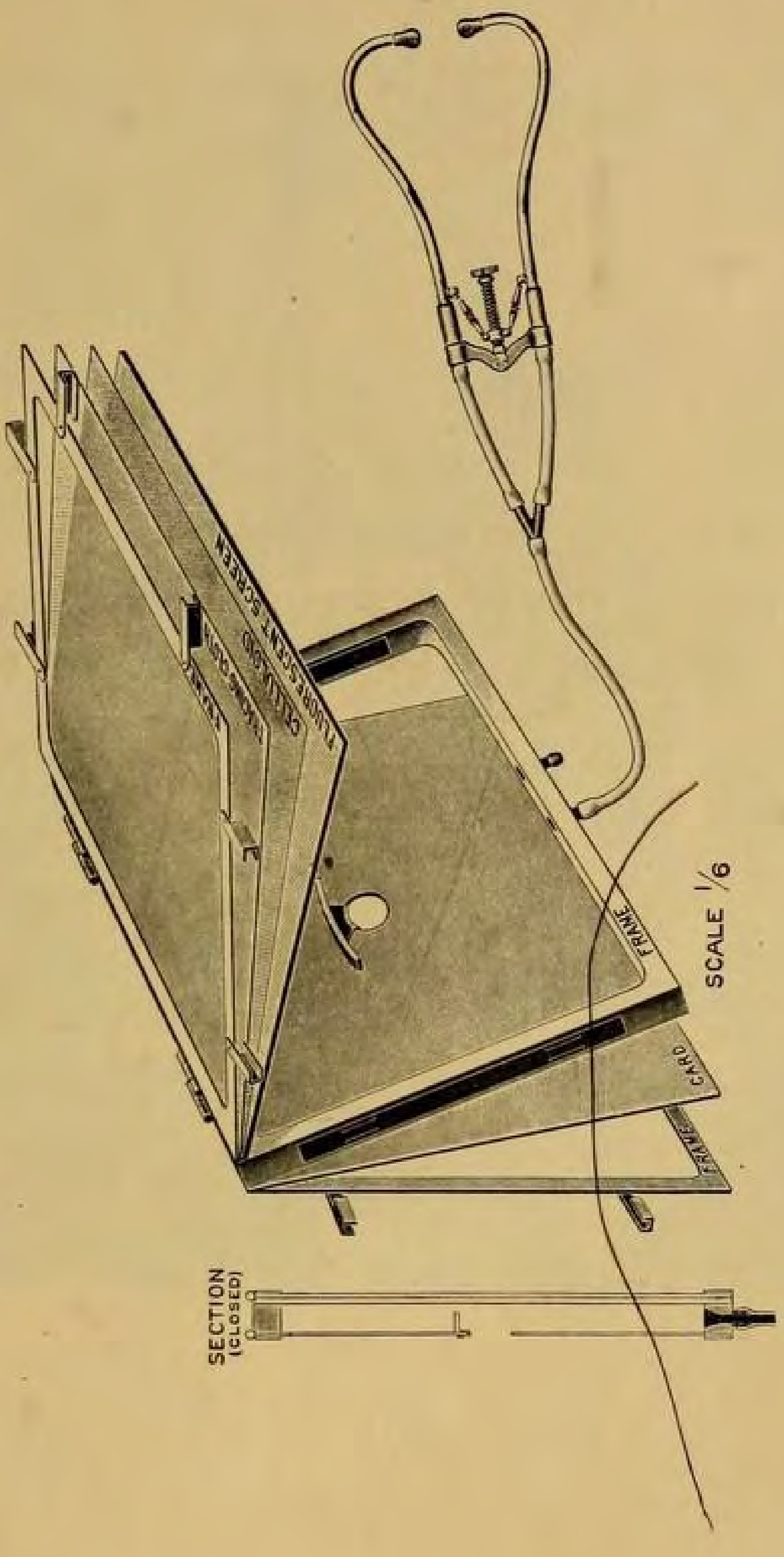
NOTE 46 — FIGURE 45 — AN X-LIGHT TUBE RUN OUT OF HARMONY WITH THE GENERATOR TO SHOW THE EFFECT OF DISCORD



NOTE 46 — FIGURE 44 — COOLED TARGET X-LIGHT TUBE SHOWING EFFECTS OF THE ANODE RUSH

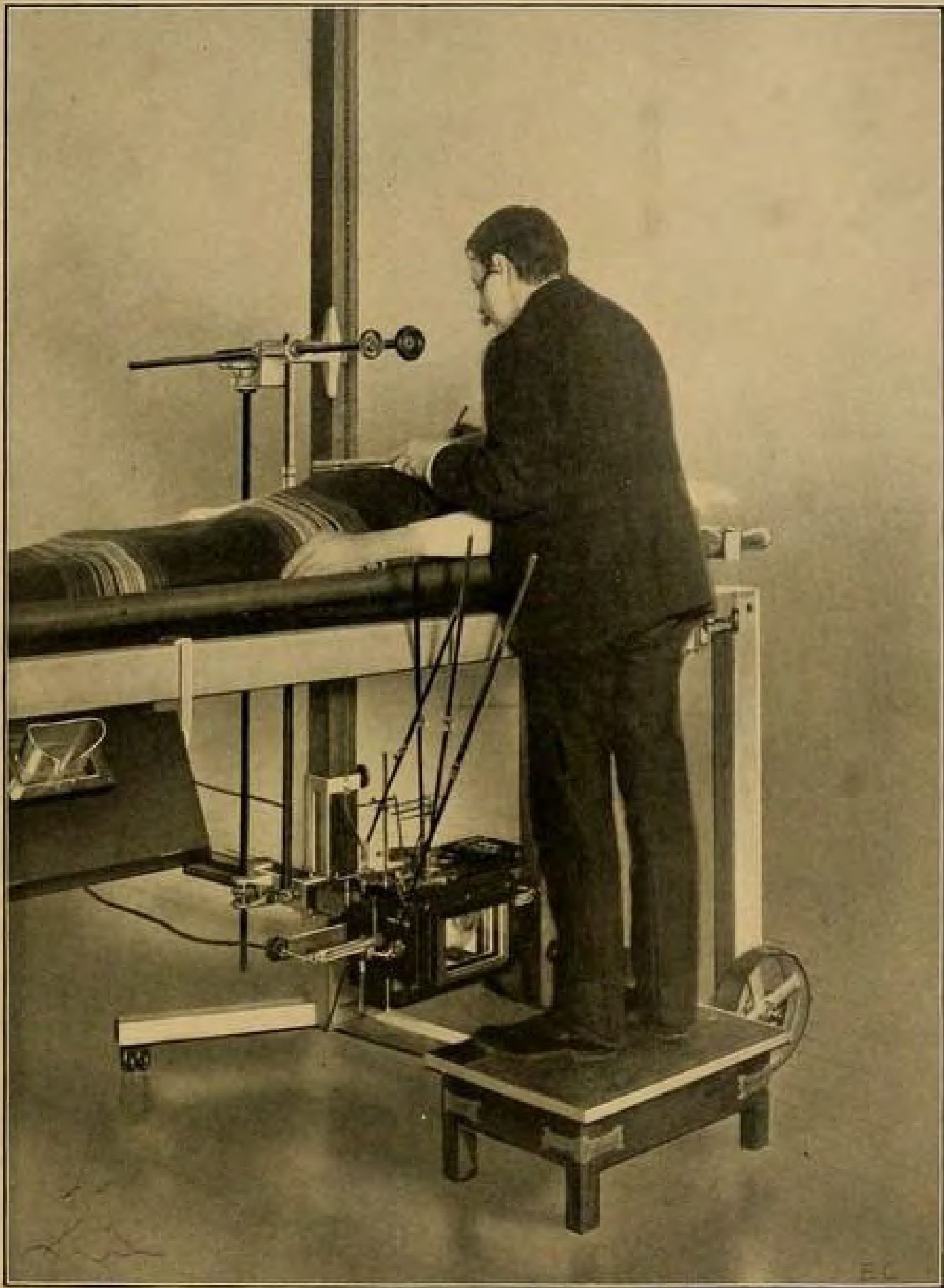
NOTE 47 — FIGURE 46 — THE SEEHEAR AND TRACING ARRANGEMENTS FOR MAKING DIAGRAMS OF THE INTERNAL ORGANS IN X-LIGHT EXAMINATIONS

Plate 19

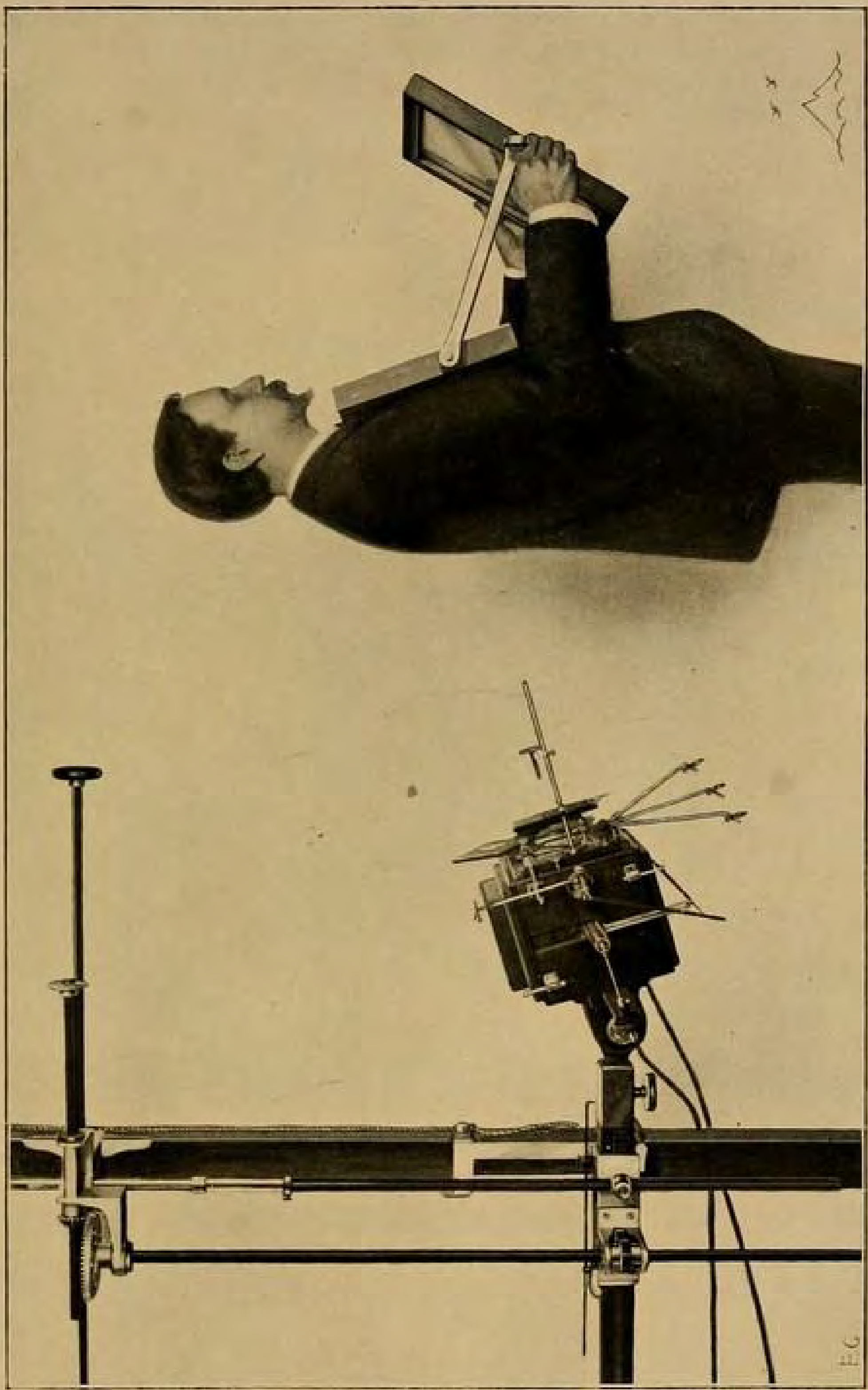


FLUORESCENT SCREEN
CELLULOID
FRAME
CARD
FRAME
SCALE 1/6
SECTION
(CLOSED)

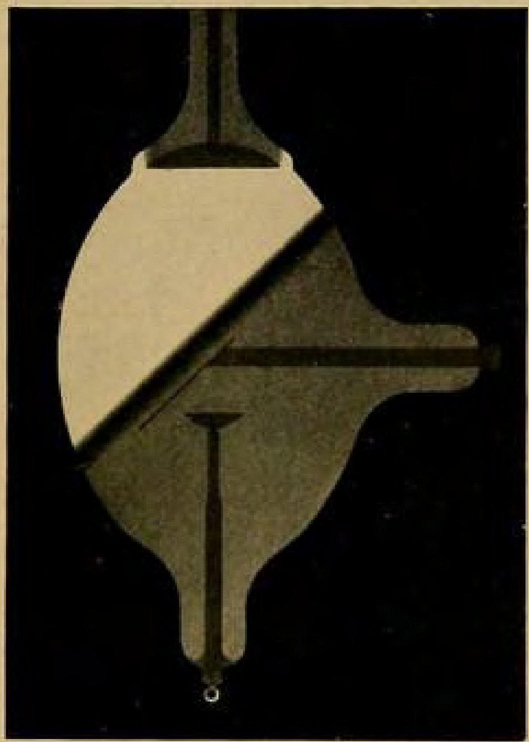
NOTE 47—FIGURE 47—SHOWING SEEHEAR IN USE



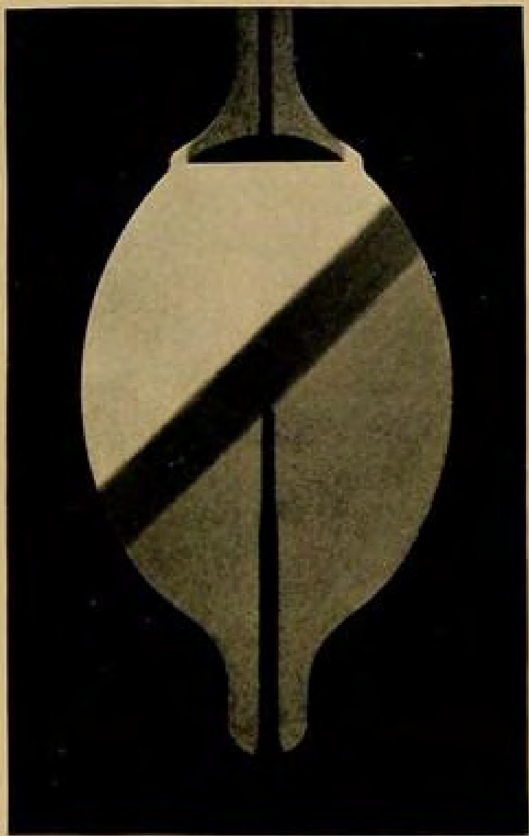
NOTE 48 — FIGURE 48 — REFLECTING CRYPTOSCOPE AND NON-RADIABLE TUBE BOX WITH A DIAPHRAGM



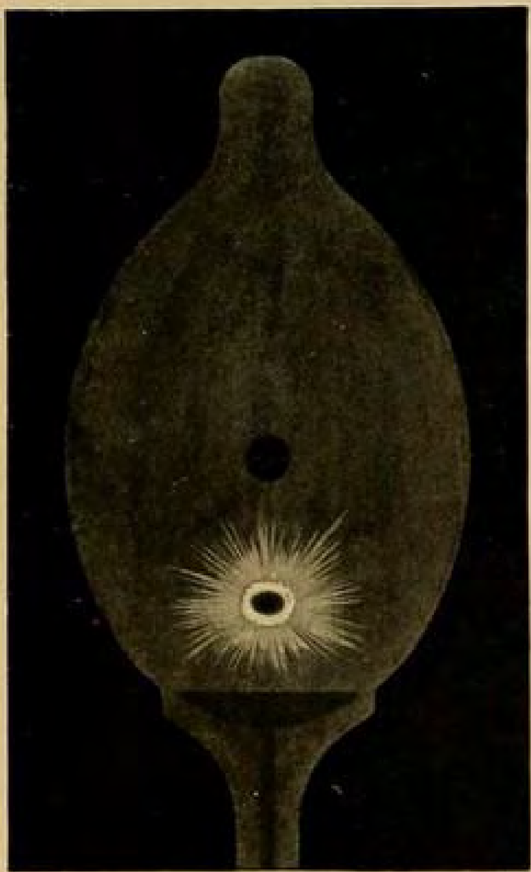
NOTE 49 — FIGURE 49 — X-LIGHT TUBE WITH THE TARGET BETWEEN CATHODE AND ANODE SHOWING THE "GIRDLE"



NOTE 49 — FIGURE 50 — THE GIRDLE OF AN X-LIGHT TUBE



NOTE 49 — FIGURE 51 — THE CORONA OF AN X-LIGHT TUBE



NOTE 50—FIGURE 52—REVOLVING TARGET X-LIGHT TUBE WITH OXYGEN AND HYDROGEN REGULATORS

NOTE 49—FIGURE 142

NOTE 50—FIGURE 53—FULL-SIZE VIEW OF REVOLVING TARGET

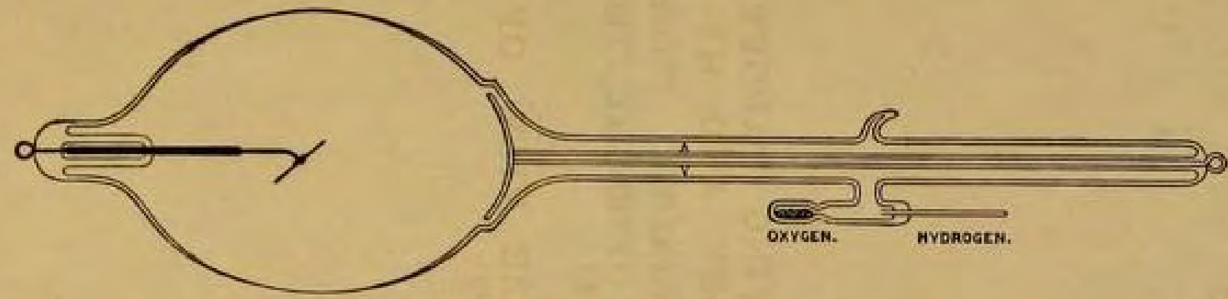


Figure 52

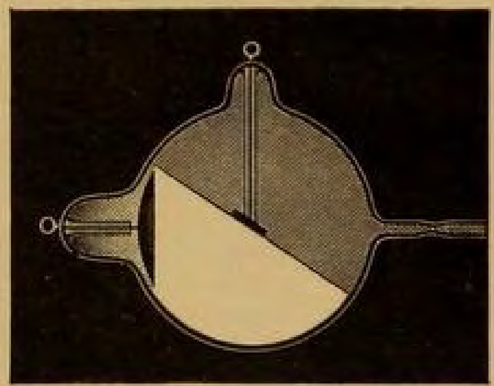


Figure 142

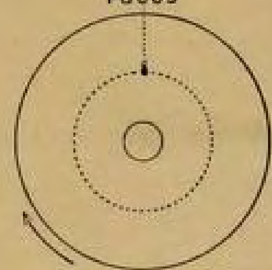


Figure 53

NOTE 58 — FIGURE 55 — AN X-LIGHT TUBE WITH HOLLOW TERMINALS OPEN TO THE ATMOSPHERE AT ONE END

NOTE 60 — FIGURE 56 — A ROTARY TARGET X-LIGHT TUBE WITH AN INTERMOLECULAR VACUUM REGULATOR AND TERMINALS WITH BARE STEMS

NOTE 62 — FIGURE 57 — A METHOD OF INTRODUCING ELECTROLYTIC HYDROGEN INTO AN X-LIGHT TUBE

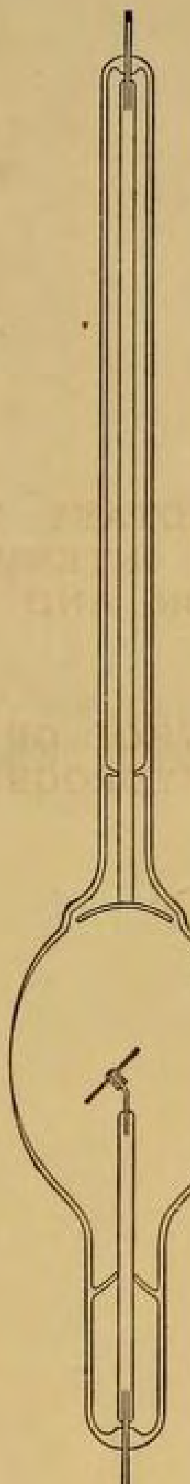


Figure 56

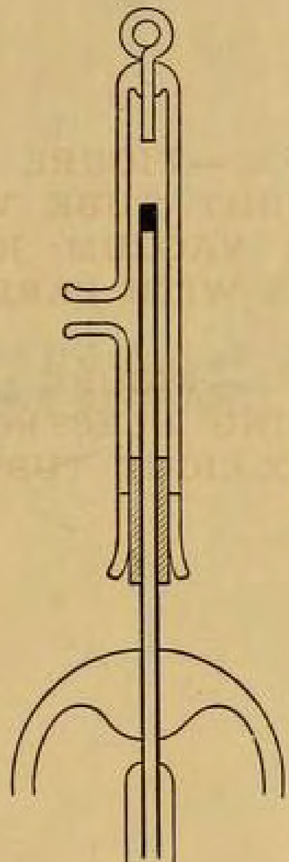
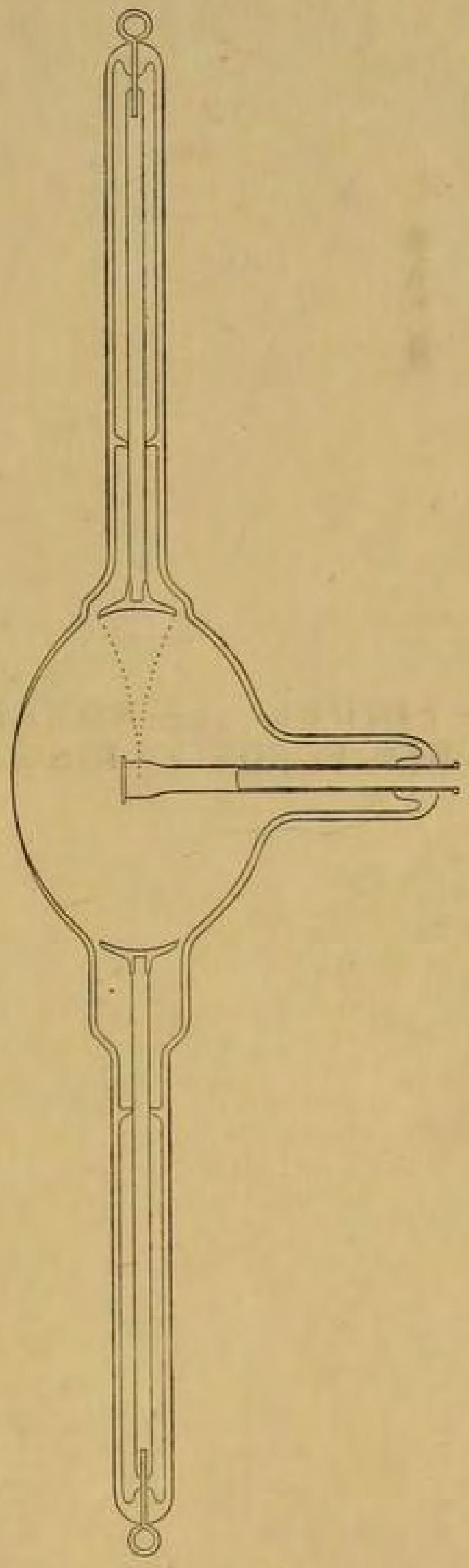
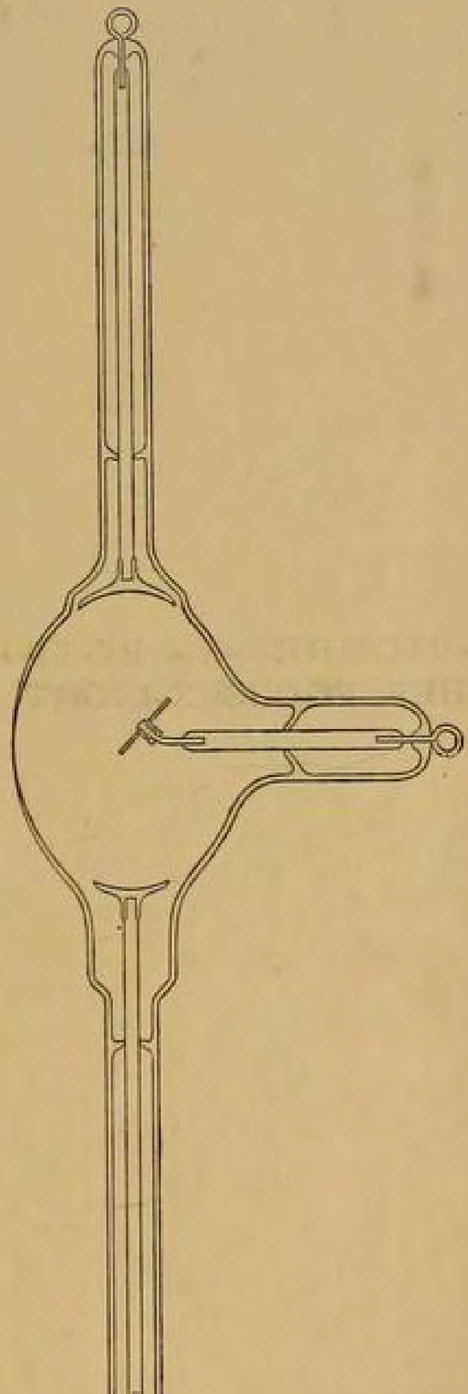


Figure 57

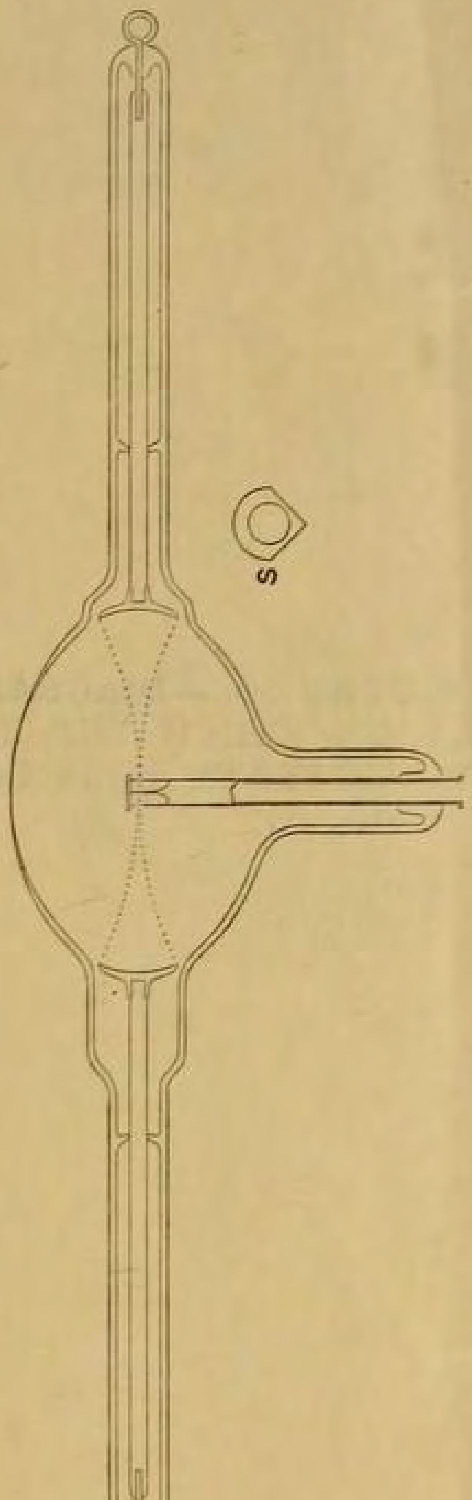
NOTE 65—FIGURE 58—COOLED TARGET DOUBLE FOCUS X-LIGHT TUBE



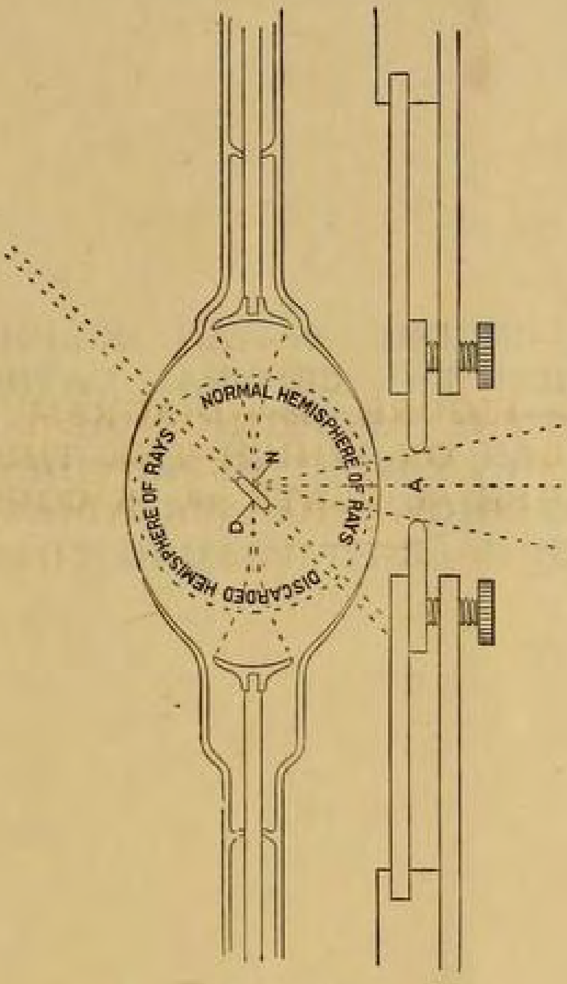
NOTE 65—FIGURE 59—ROTARY TARGET DOUBLE FOCUS X-LIGHT TUBE



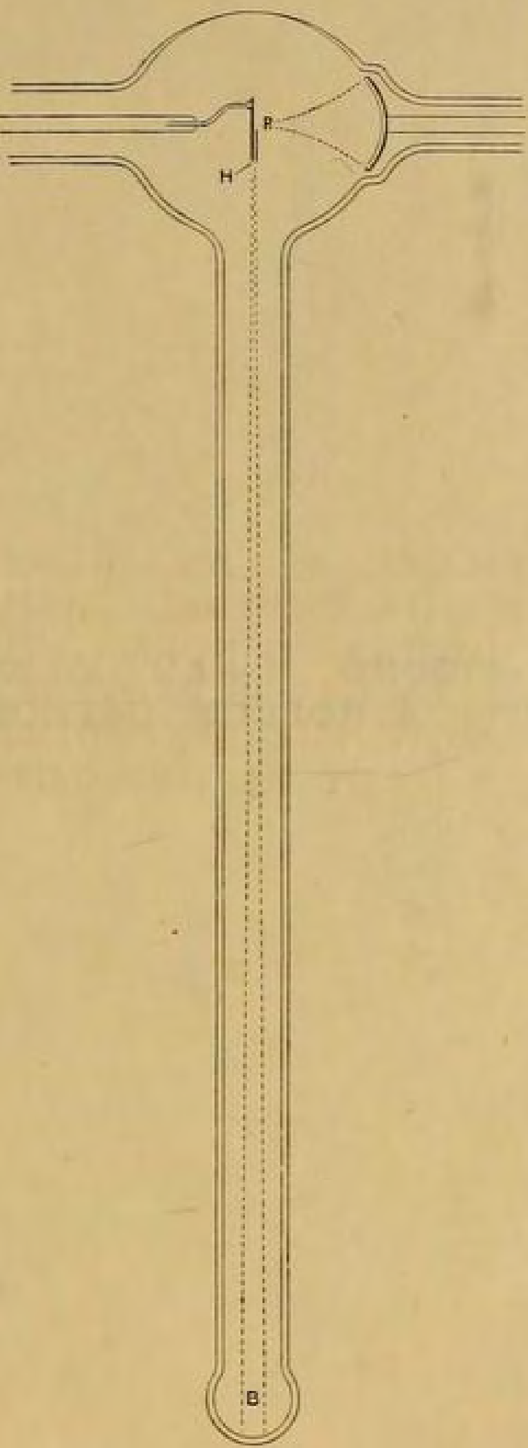
NOTE 65—FIGURE 61—COOLED TARGET DOUBLE FOCUS X-LIGHT TUBE


S

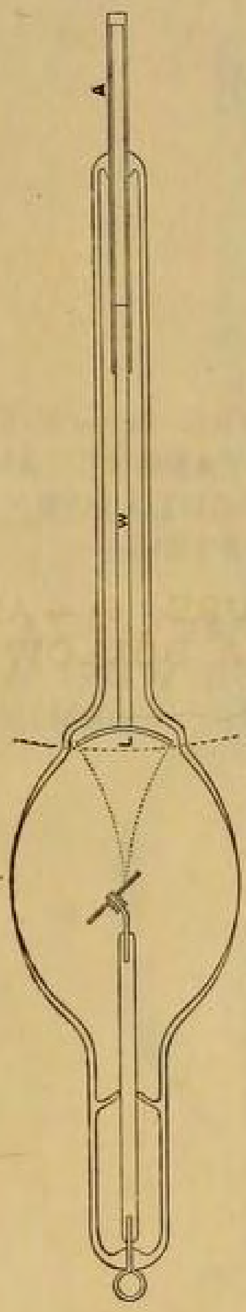
NOTE 65 — FIGURE 60 — DIAGRAM SHOWING THE PLAN ON WHICH THE TUBE SHOWN IN FIGURE 58, PLATE 28, IS CONSTRUCTED


NORMAL HEMISPHERE OF RAYS
DISCARDED HEMISPHERE OF RAYS
N
D
A

NOTE 69 — FIGURE 62 — AN X-LIGHT TUBE IN WHICH THE CENTRAL CATHODE RAY STRIKES THE TARGET NORMAL TO ITS SURFACE. THE TARGET IS PROVIDED WITH A SLIT TO SHOW THE SPREADING OF THE BEAM OF X-LIGHT PASSING THROUGH IT


P
H
B

NOTE 70 — FIGURE 63 — AN X-LIGHT TUBE WITH A HOLLOW CATHODE



NOTE 80—FIGURE 64—X-LIGHT TUBE WITH A ROTARY TARGET AND A PALLADIUM VACUUM REGULATOR, THE TERMINALS WITH BARE STEMS

NOTE 80—FIGURE 65—A COOLED TARGET X-LIGHT TUBE WITH A PALLADIUM REGULATOR, THE TERMINALS WITH BARE STEMS

Figure 64

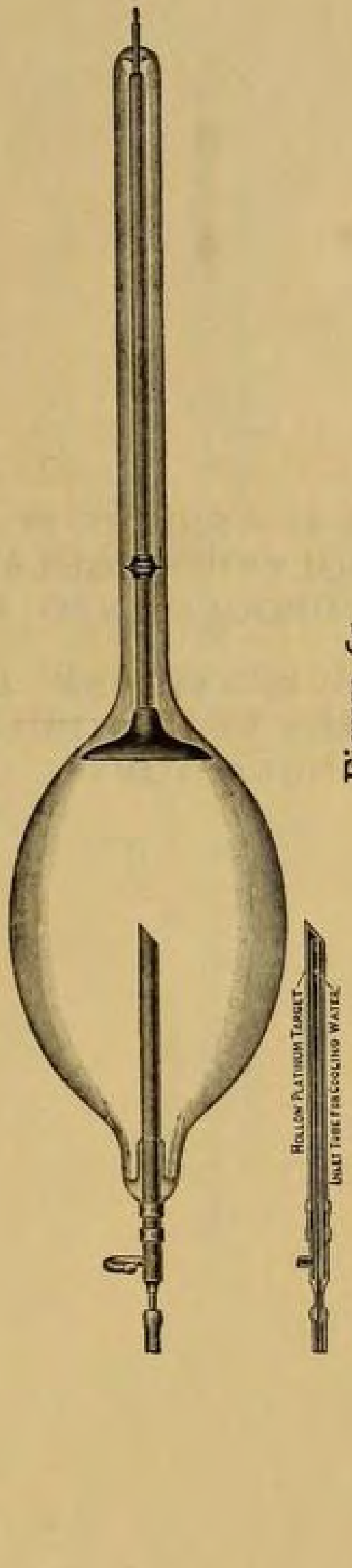


Figure 65

NOTE 80 — FIGURE 68 — DETAILS OF AN ELECTROLYTIC REGULATOR FOR INTRODUCING HYDROGEN INTO AN X-LIGHT TUBE

NOTE 84 — FIGURE 69 — AN X-LIGHT TUBE MADE FROM A BULB MOULDED IN A GLASS MANUFACTORY

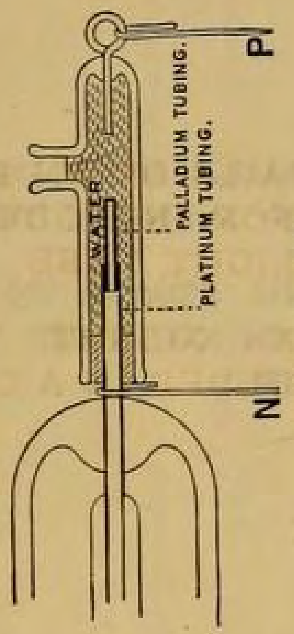


Figure 68

Figure 69

NOTE 84 — FIGURE 70 — A BULB MOULDED IN A GLASS HOUSE FOR AN X-LIGHT TUBE

NOTE 84 — FIGURE 71 — ONE STAGE IN THE PROCESS OF MAKING AN X-LIGHT TUBE FROM A MOULDED BULB

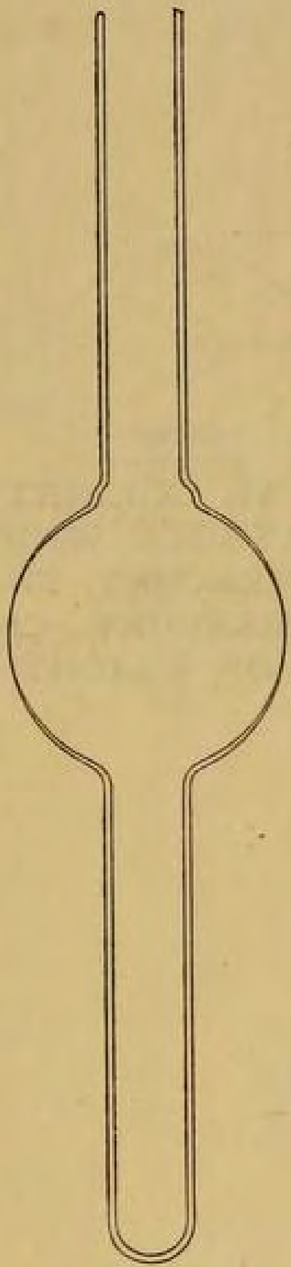


Figure 70

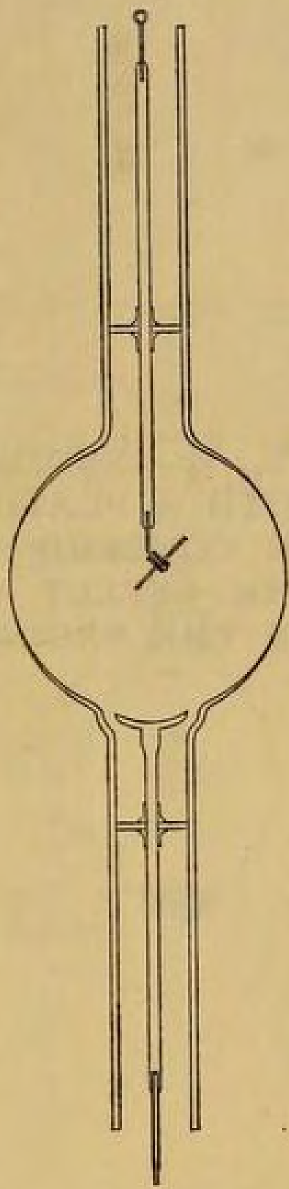
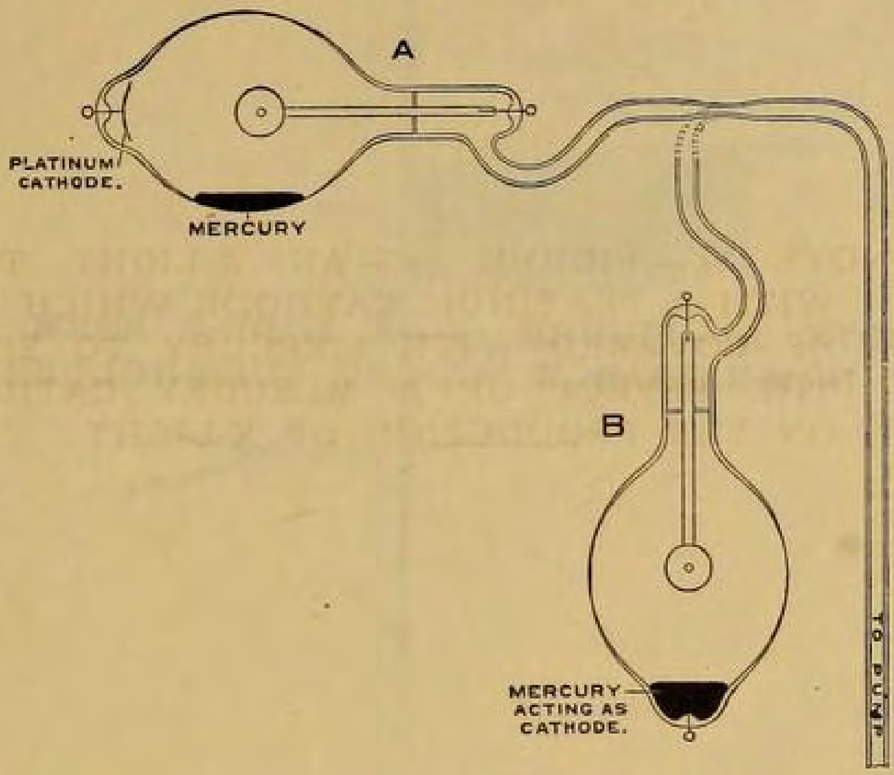
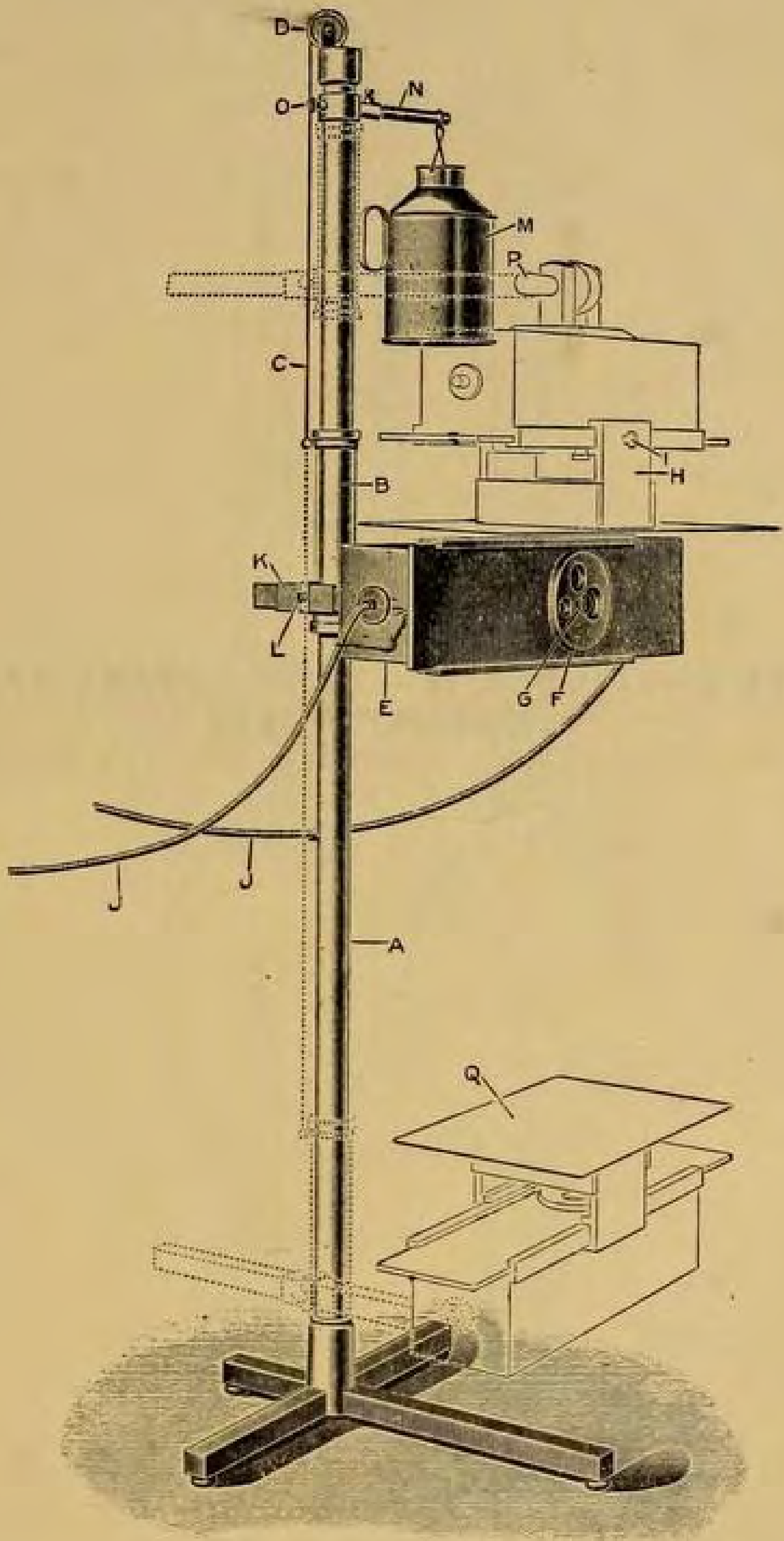


Figure 71

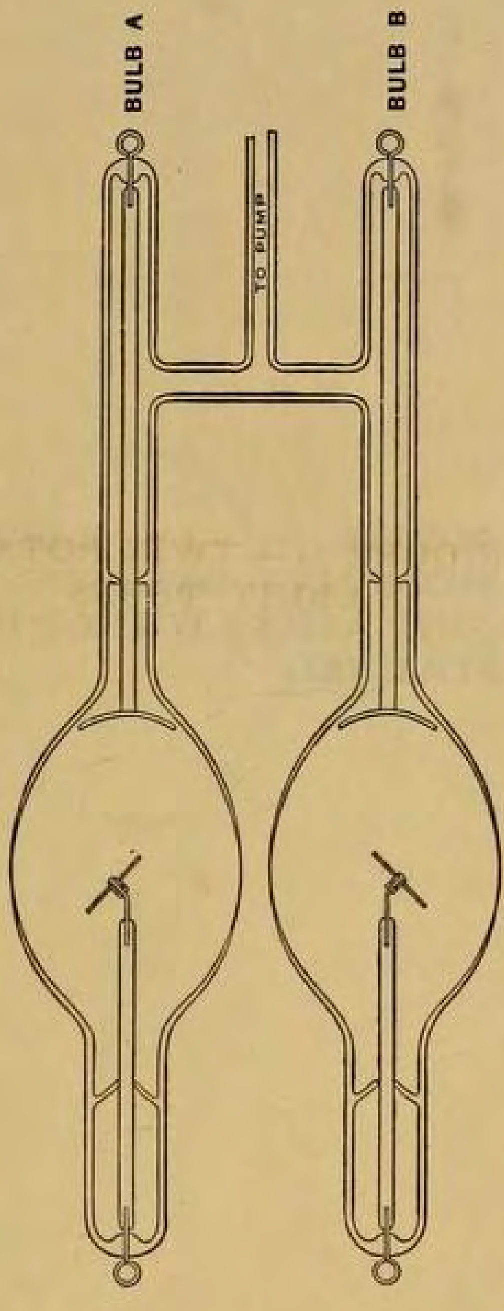
NOTE 85—FIGURE 72—AN X-LIGHT TUBE WITH A PLATINUM CATHODE WHICH CAN BE COVERED WITH MERCURY TO SHOW THE EFFECT OF A MERCURY CATHODE ON THE PRODUCTION OF X-LIGHT


A
PLATINUM CATHODE.
MERCURY
B
MERCURY ACTING AS CATHODE.
TO PUMP

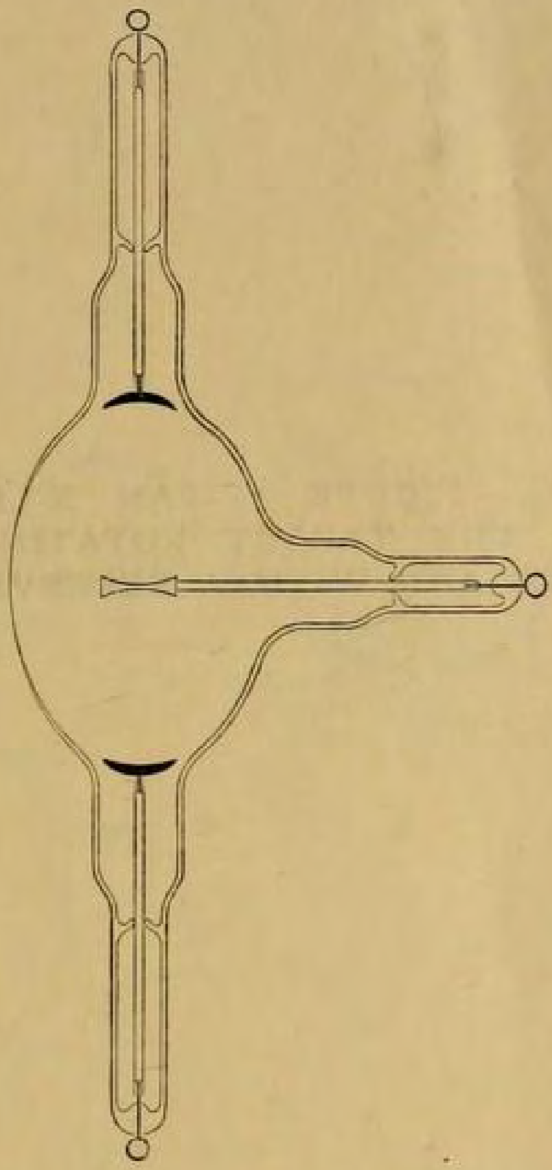
NOTE 94 — FIGURE 73 — A SIMPLE FORM OF NON-RADIABLE X-LIGHT TUBE-HOLDER


D
N
O
M
P
C
H
B
K
L
E
G
F
J
J
A
Q

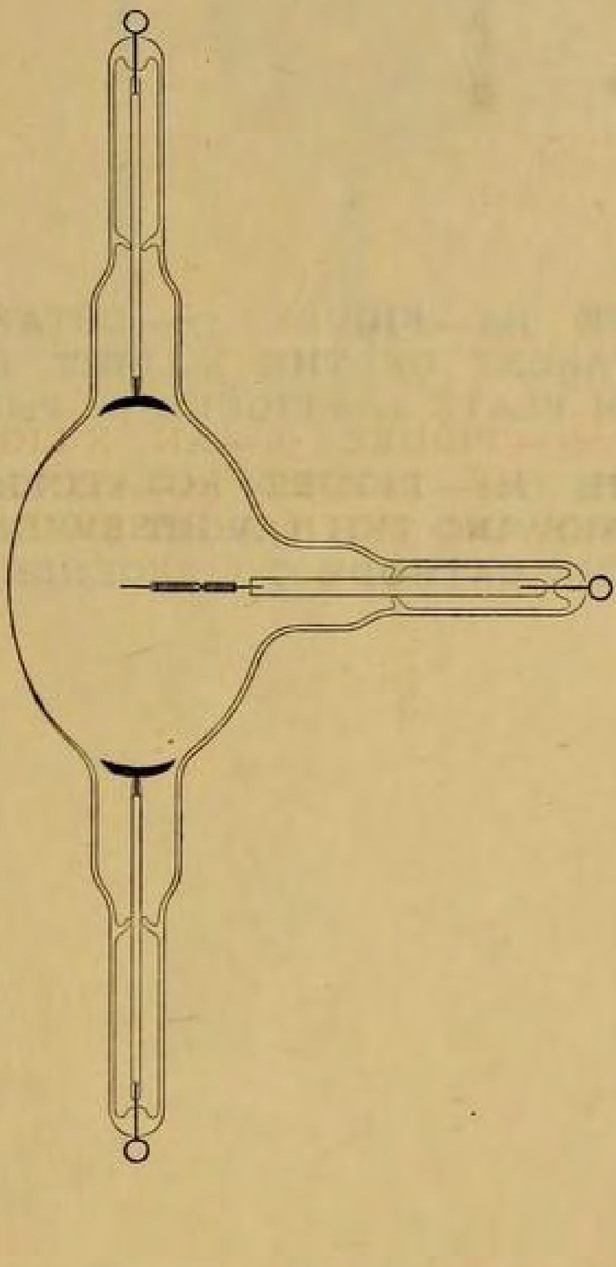
NOTE 95 — FIGURE 74 — TWIN ROTARY TARGET X-LIGHT TUBES


BULB A
BULB B
TO PUMP

NOTE 102—FIGURE 75—AN X-LIGHT TUBE WITH A BICONCAVE CATHODE, TO SHOW THAT X-LIGHT ARISES WHERE THE ETHER IS MOST STRAINED



NOTE 103 — FIGURE 76 — AN X-LIGHT TUBE WITH THE TARGET ROTATING IN TWO PLANES AND WITH A RESERVE CATHODE



NOTE 103 — FIGURE 77 — DETAILS OF THE TARGET OF THE X-LIGHT TUBE SHOWN IN PLATE 41 — FIGURE 76 -Full Size-

NOTE 103 — FIGURE 78 — SECTIONAL VIEW, SHOWING THE TARGET SWUNG TO ALLOW THE CATHODE TO REGENERATE

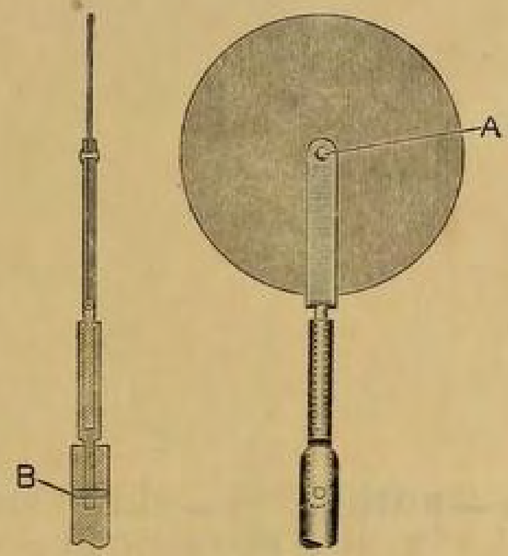


Figure 77

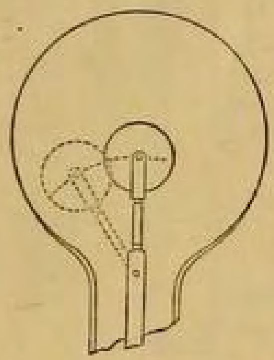


Figure 78

NOTE 112—FIGURE 79—SECTION OF MULTIPLE SPARK-GAP

NOTE 112—FIGURE 80—MULTIPLE SPARK-GAPS APPLIED TO A COIL

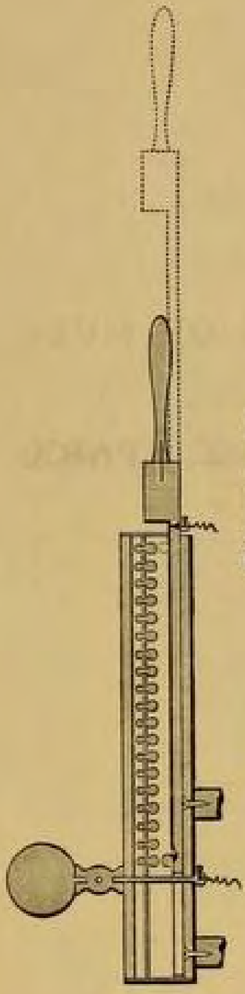


Figure 79

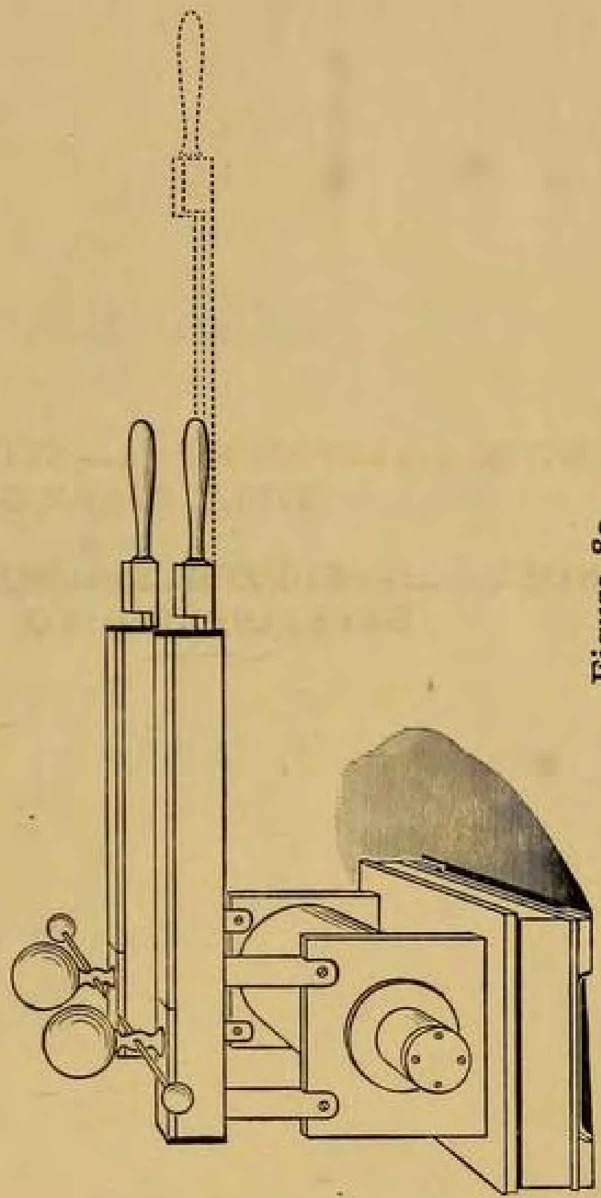
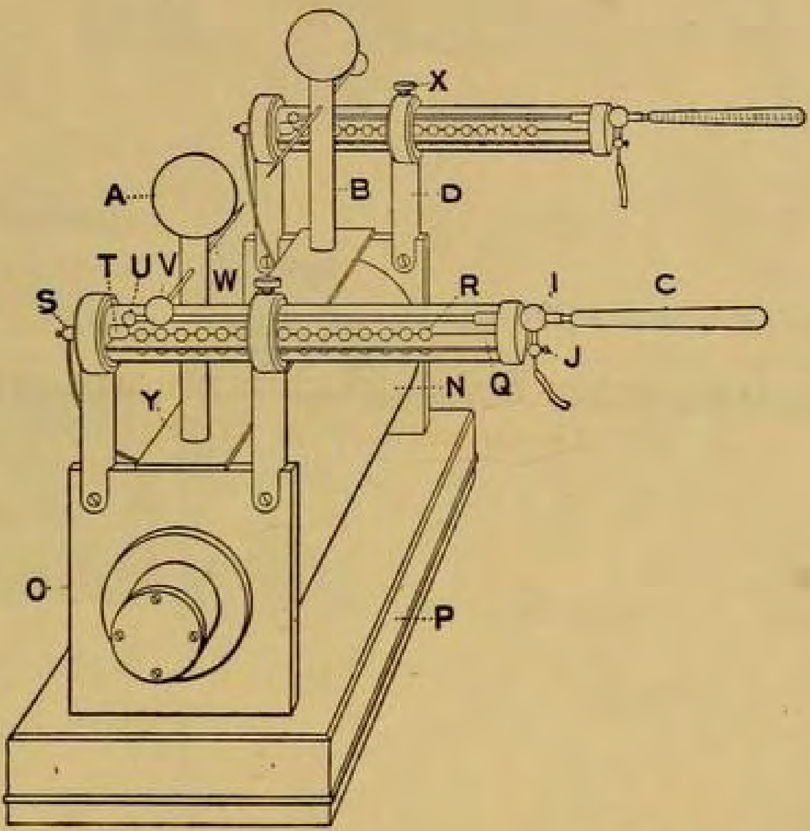
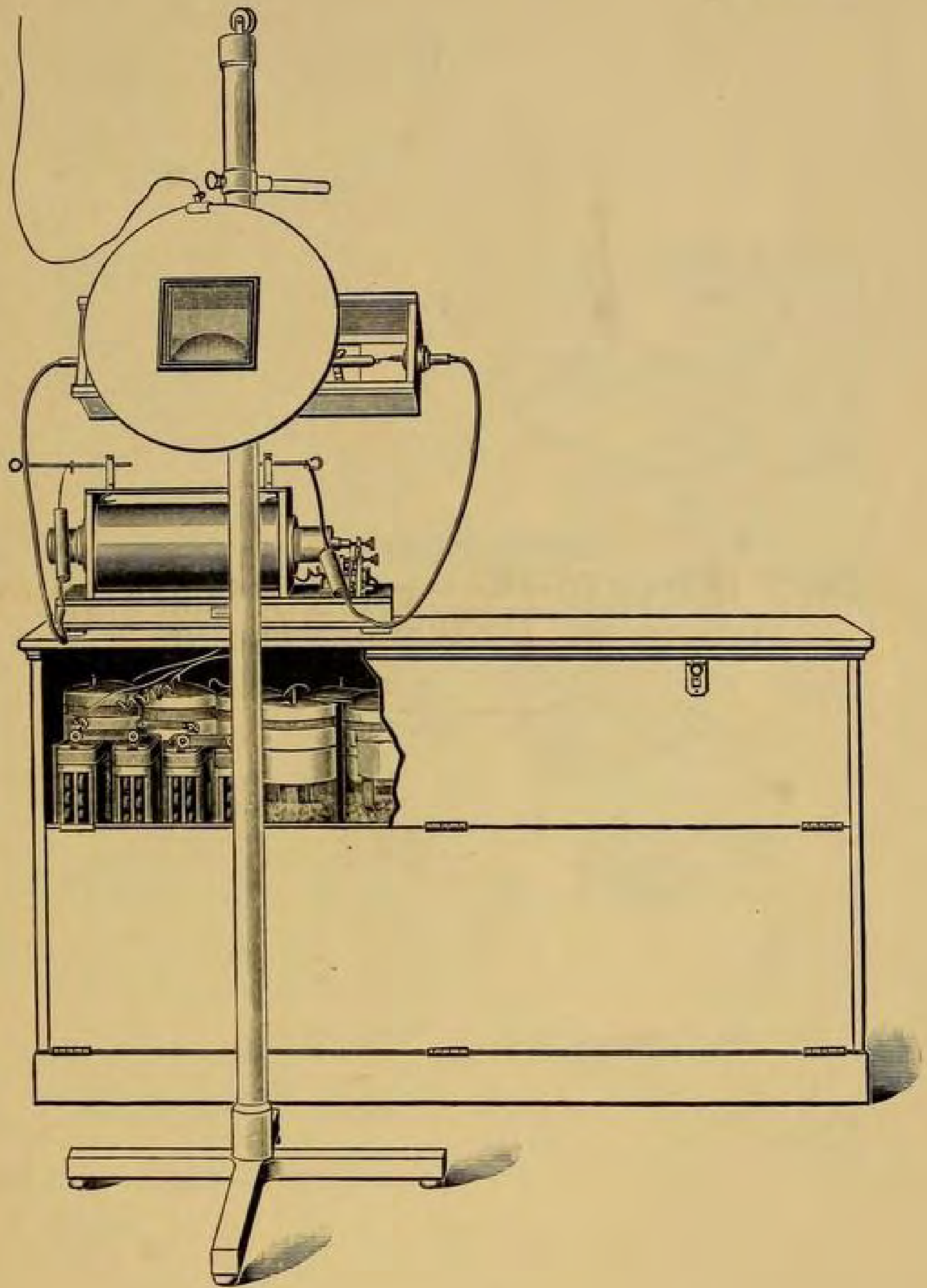


Figure 80

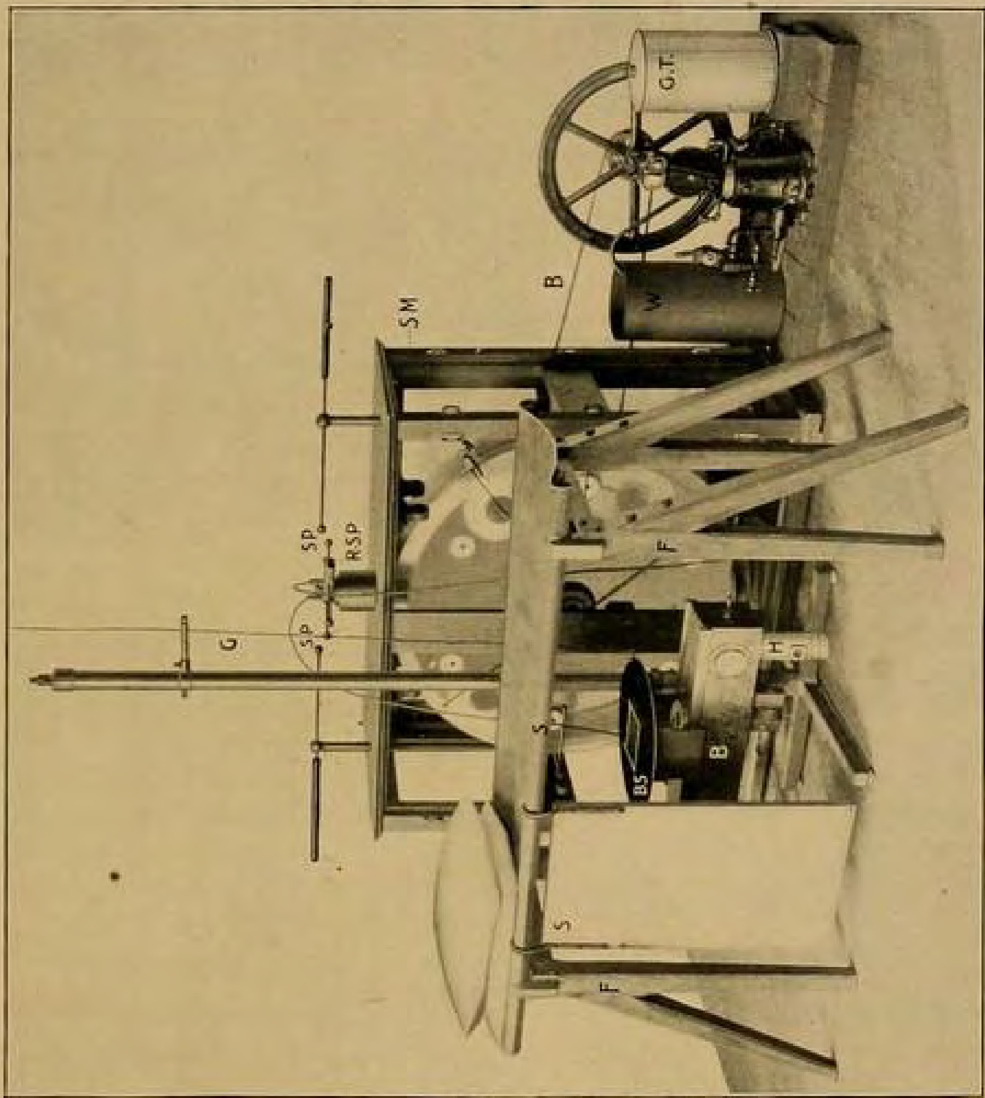
NOTE 112 — FIGURE 81 — ENCLOSED MULTIPLE SPARK-GAPS ON A COIL


X
A
B
D
T U V
W
S
R
I
C
J
N
Q
Y
O
P

NOTE 112 — FIGURE 82 — A COIL OPERATED BY STORAGE CELLS



NOTE 112 — FIGURE 83 — A STATIC MACHINE DRIVEN BY A GASOLINE ENGINE


G.T.
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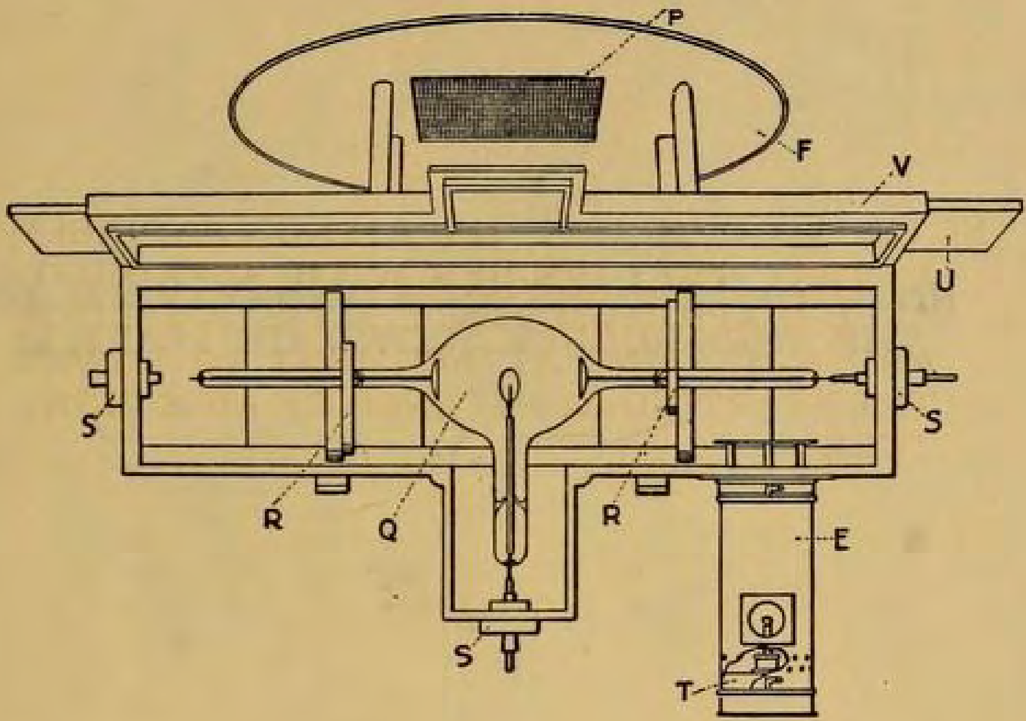
NOTE 112 — FIGURE 84 — A NON-RADIABLE X-LIGHT TUBE-HOLDER WITH AN ADJUSTABLE DIAPHRAGM PLATE, A TESLA SCREEN, AND A HEATING ATTACHMENT TO LOWER THE STARTING RESISTANCE OF AN X-LIGHT TUBE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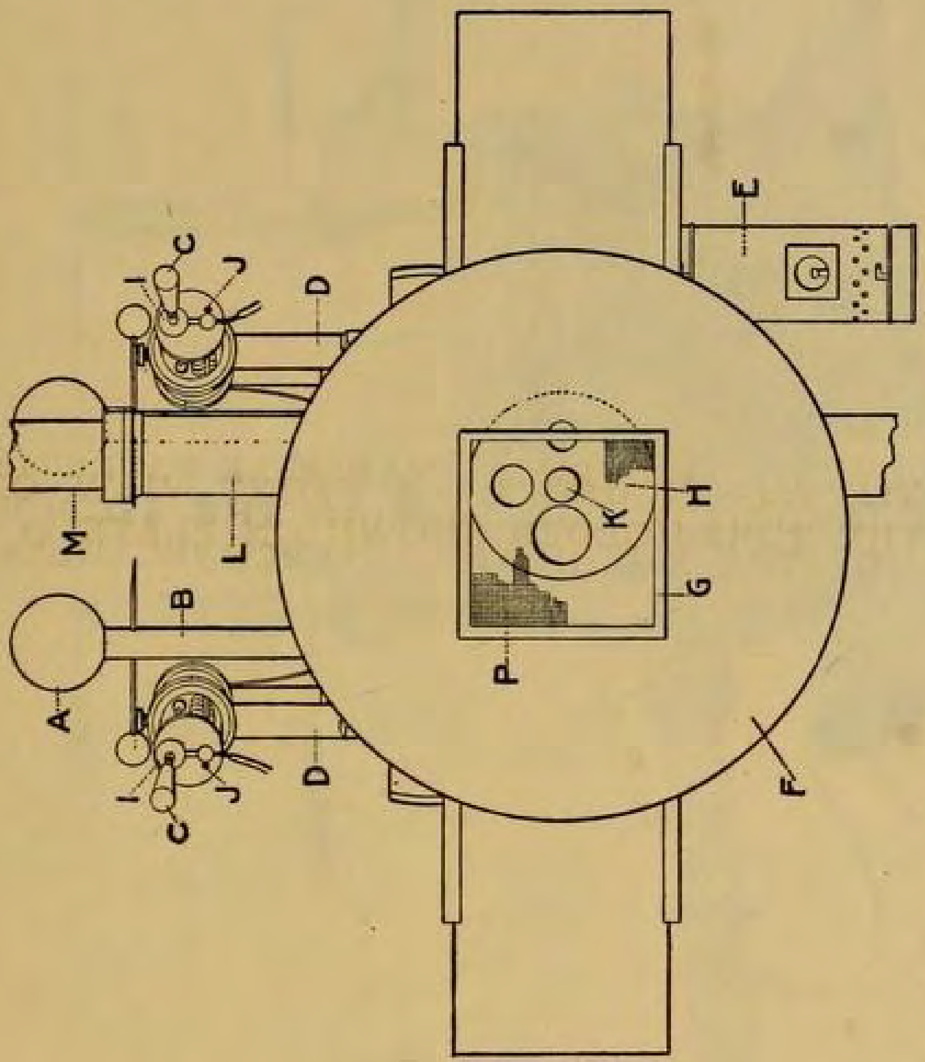
NOTE 112 — FIGURE 85 — A FRONT VIEW OF THE TUBE-HOLDER SHOWN ON PLATE 47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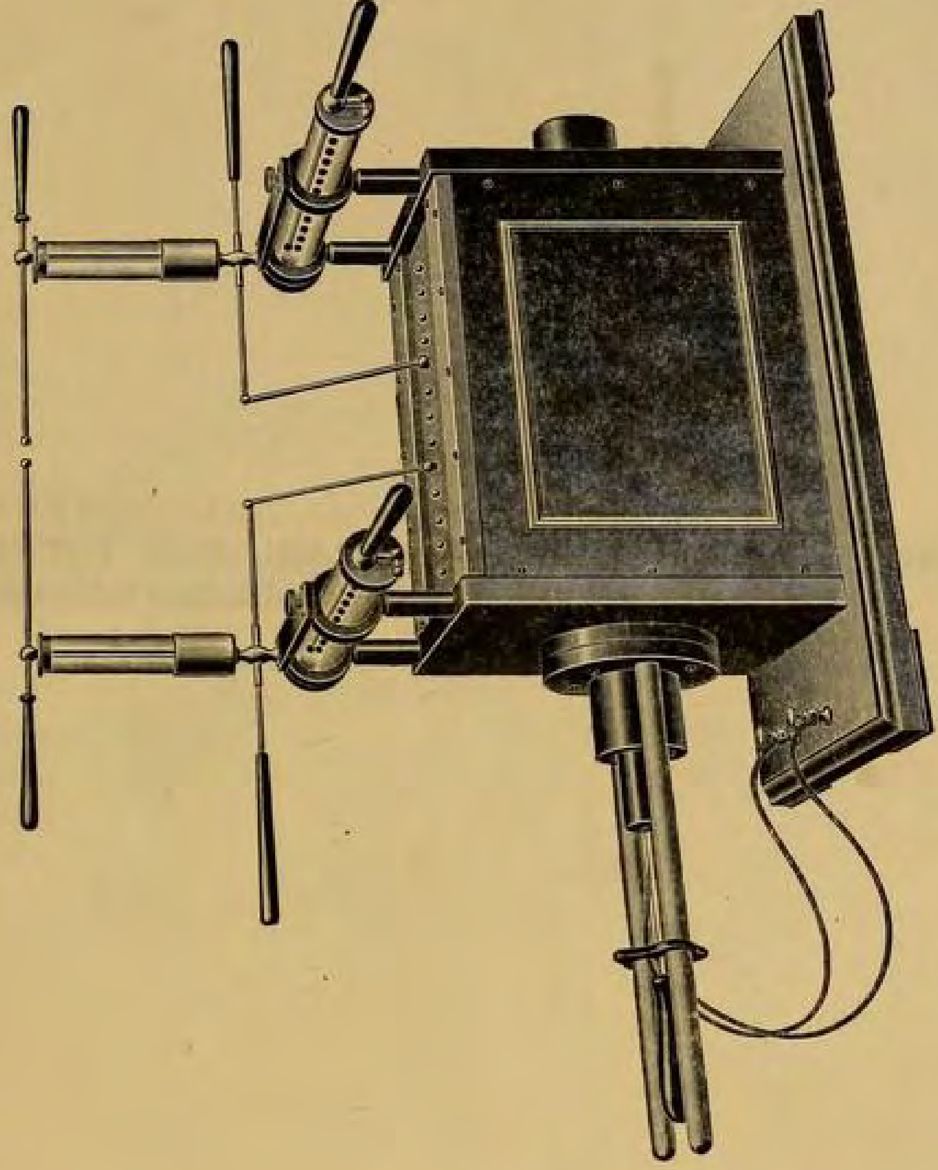
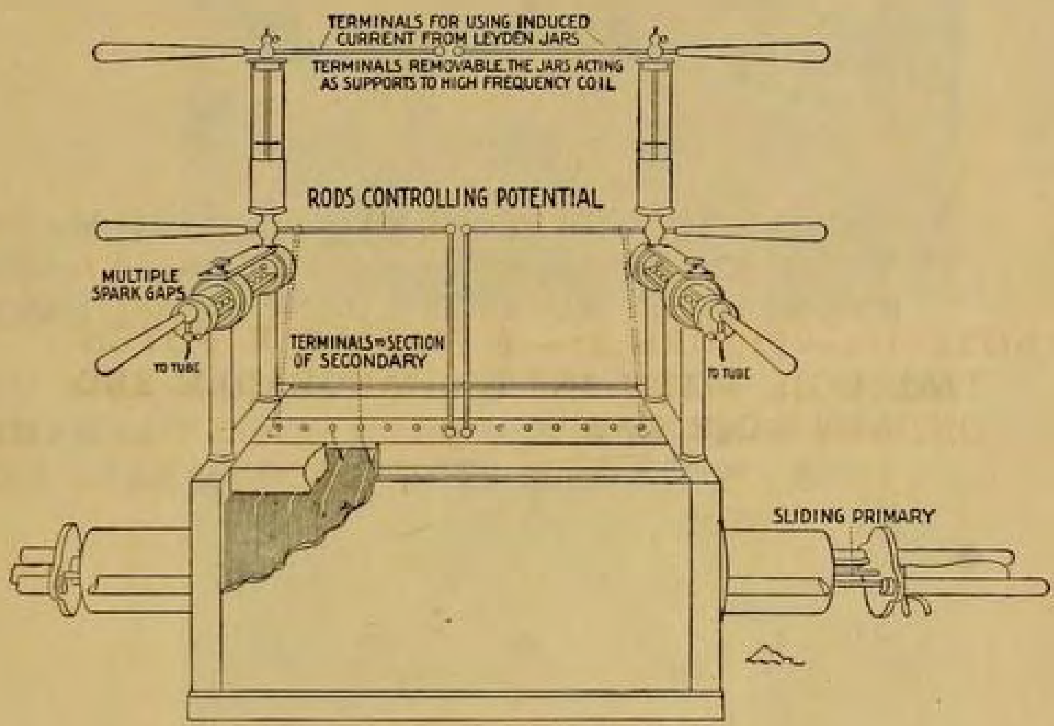
NOTE 112 — FIGURE 86 — VARIABLE POTENTIAL INDUCTION COIL HAVING THE SECTIONS OF THE SECONDARY INTERCHANGEABLE

Plate 49



NOTE 112 — FIGURE 87 — A VARIABLE POTENTIAL COIL WITH INTERCHANGEABLE SECONDARY SECTIONS


TERMINALS FOR USING INDUCED CURRENT FROM LEYDEN JARS
TERMINALS REMOVABLE. THE JARS ACTING AS SUPPORTS TO HIGH FREQUENCY COIL
RODS CONTROLLING POTENTIAL
MULTIPLE SPARK GAPS
TO TUBE
TERMINALS TO SECTION OF SECONDARY
TO TUBE
SLIDING PRIMARY

NOTE 112 — FIGURE 88 — A PHOTOGRAPH MADE WITH AN X-LIGHT TUBE HAVING A LOW RESISTANCE; NO SPARK-GAPS BEING USED

NOTE 112 — FIGURE 89 — A PHOTOGRAPH OF THE SAME SUBJECT MADE WITH THE SAME TUBE; MULTIPLE SERIES SPARK-GAPS BEING USED

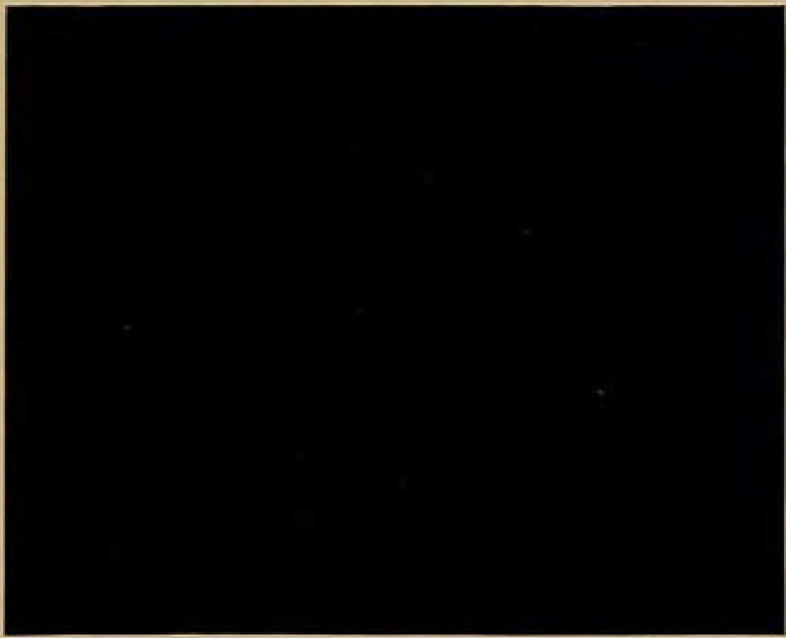


Figure 88

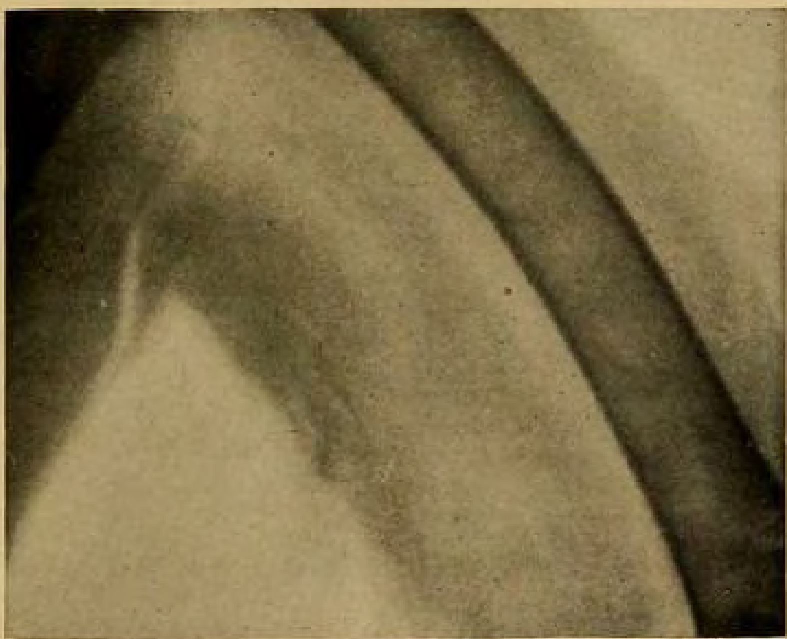
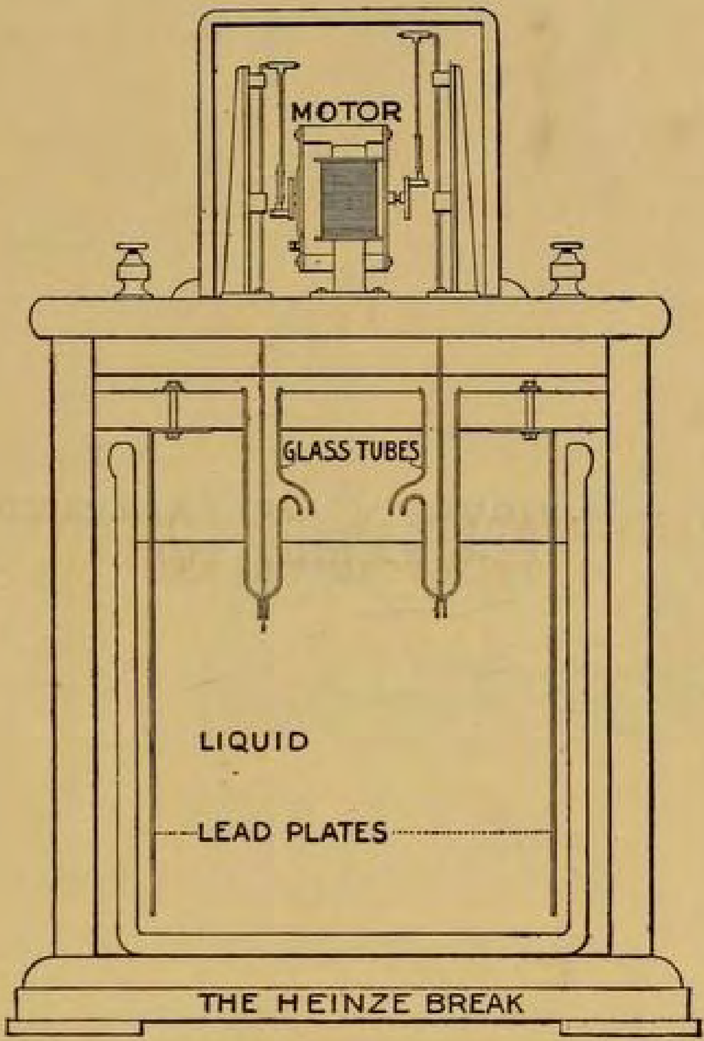
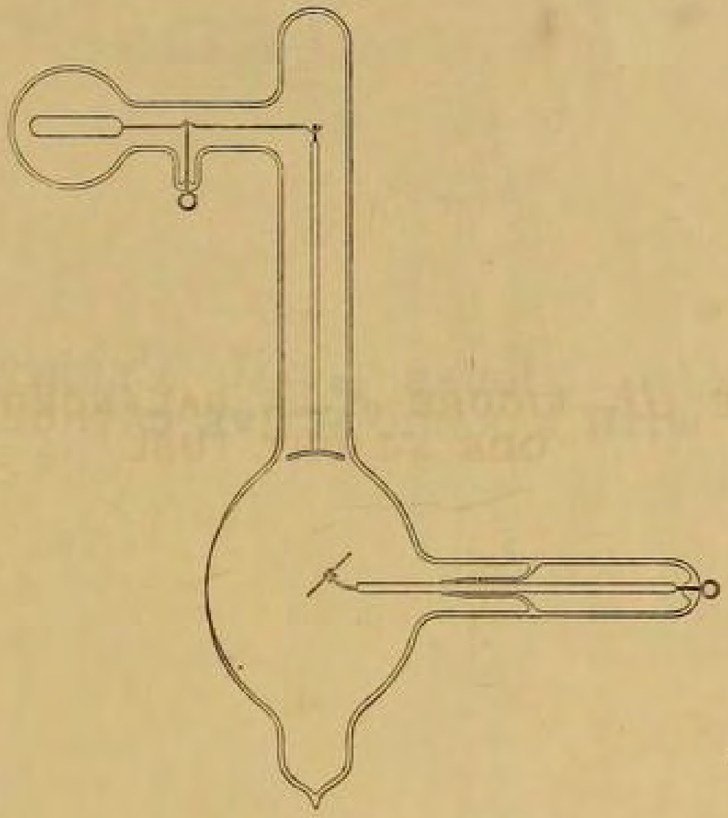


Figure 89

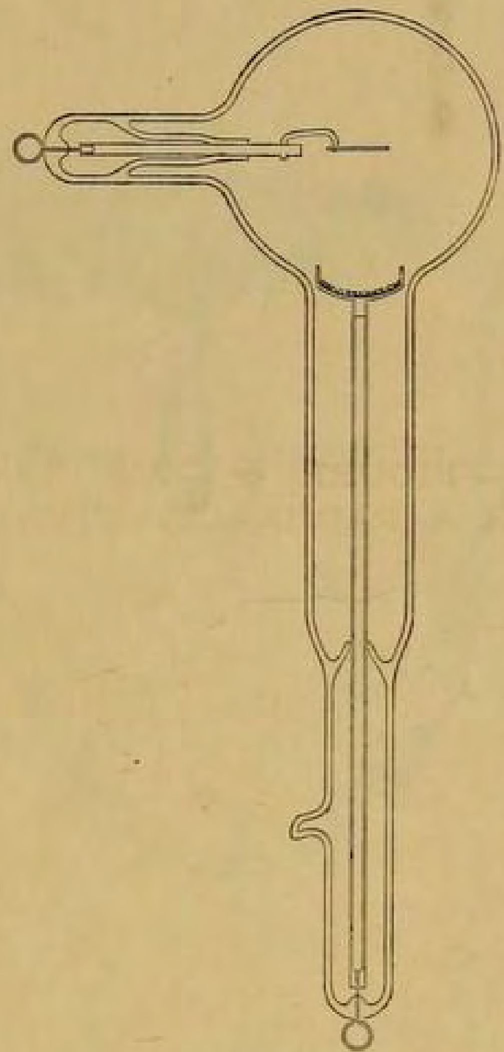
NOTE 112 — FIGURE 90 — THE HEINZE ELECTROLYTIC BREAK


MOTOR
GLASS TUBES
LIQUID
LEAD PLATES
THE HEINZE BREAK

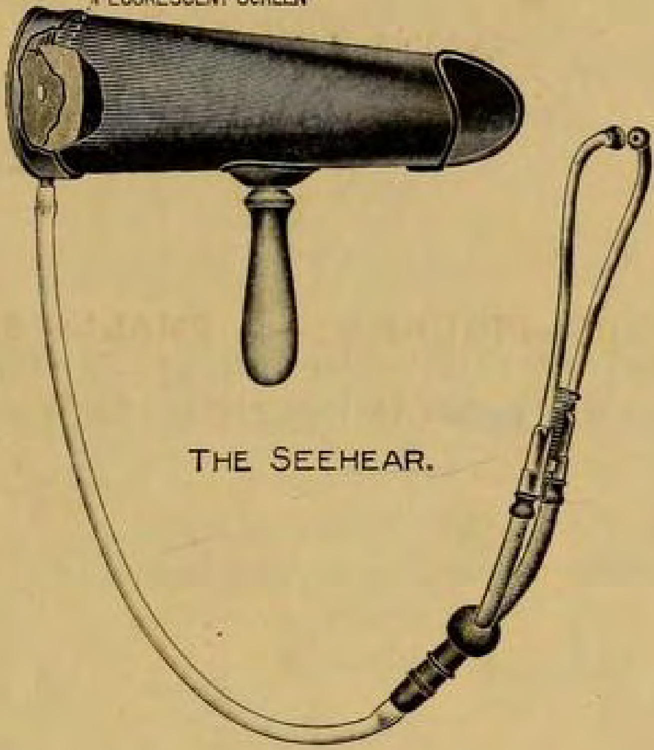
NOTE 114 — FIGURE 91 — A BALANCED CATHODE X-LIGHT TUBE



NOTE 115—FIGURE 92—AN X-LIGHT TUBE WITH A RADIO-ACTIVE CATHODE

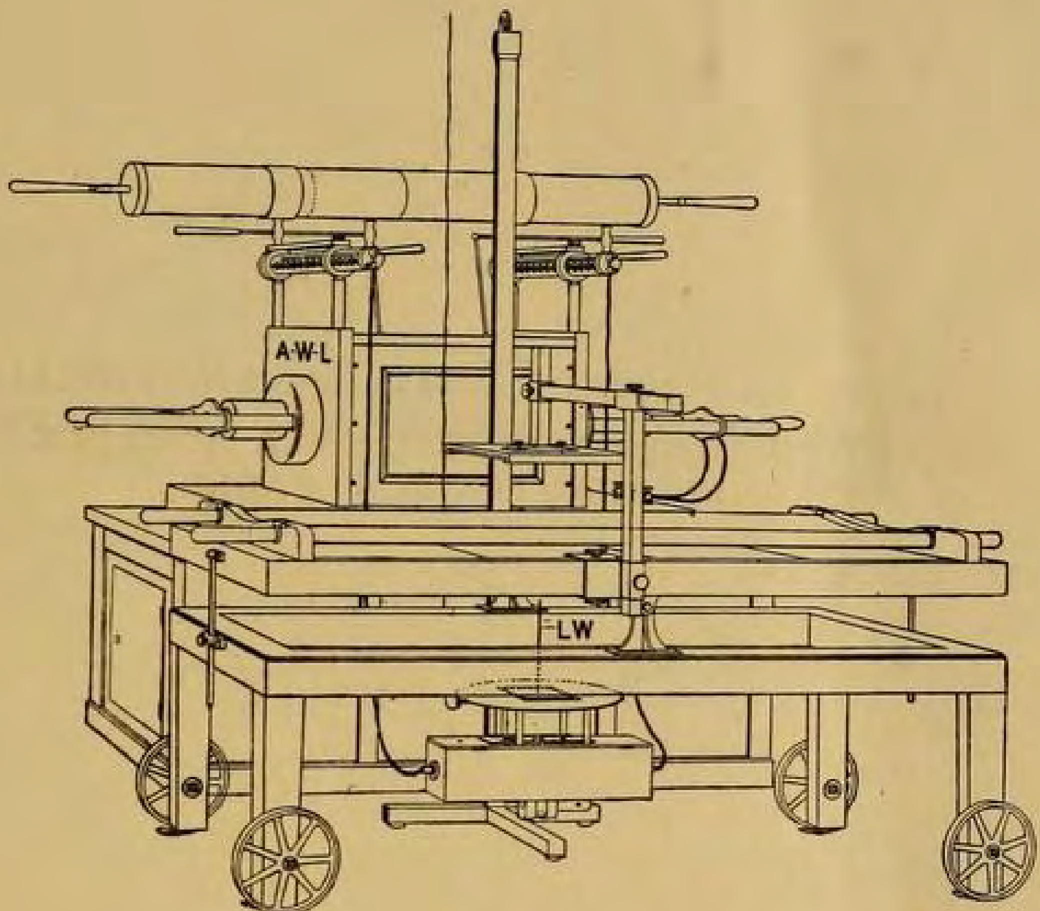


NOTE 116 — FIGURE 93 — A SMALL "SEEHEAR"

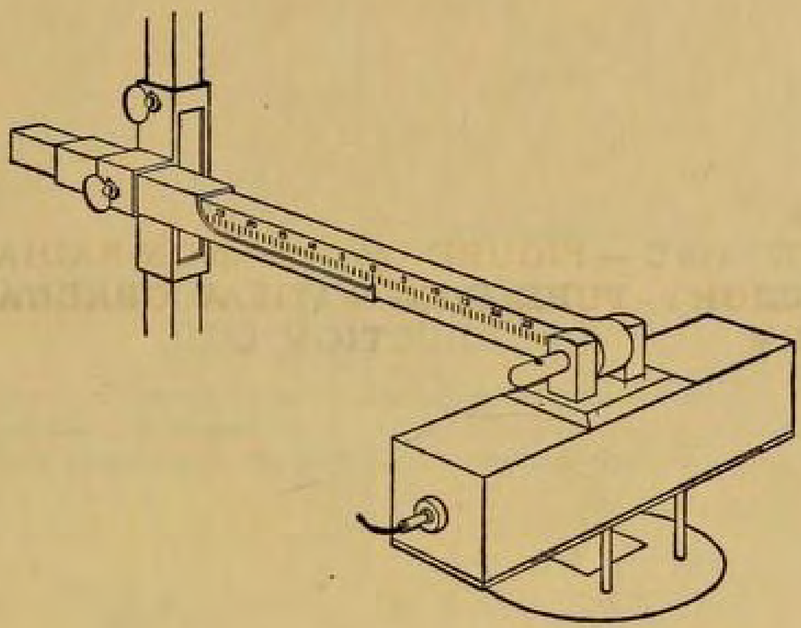


THE SEEHEAR.

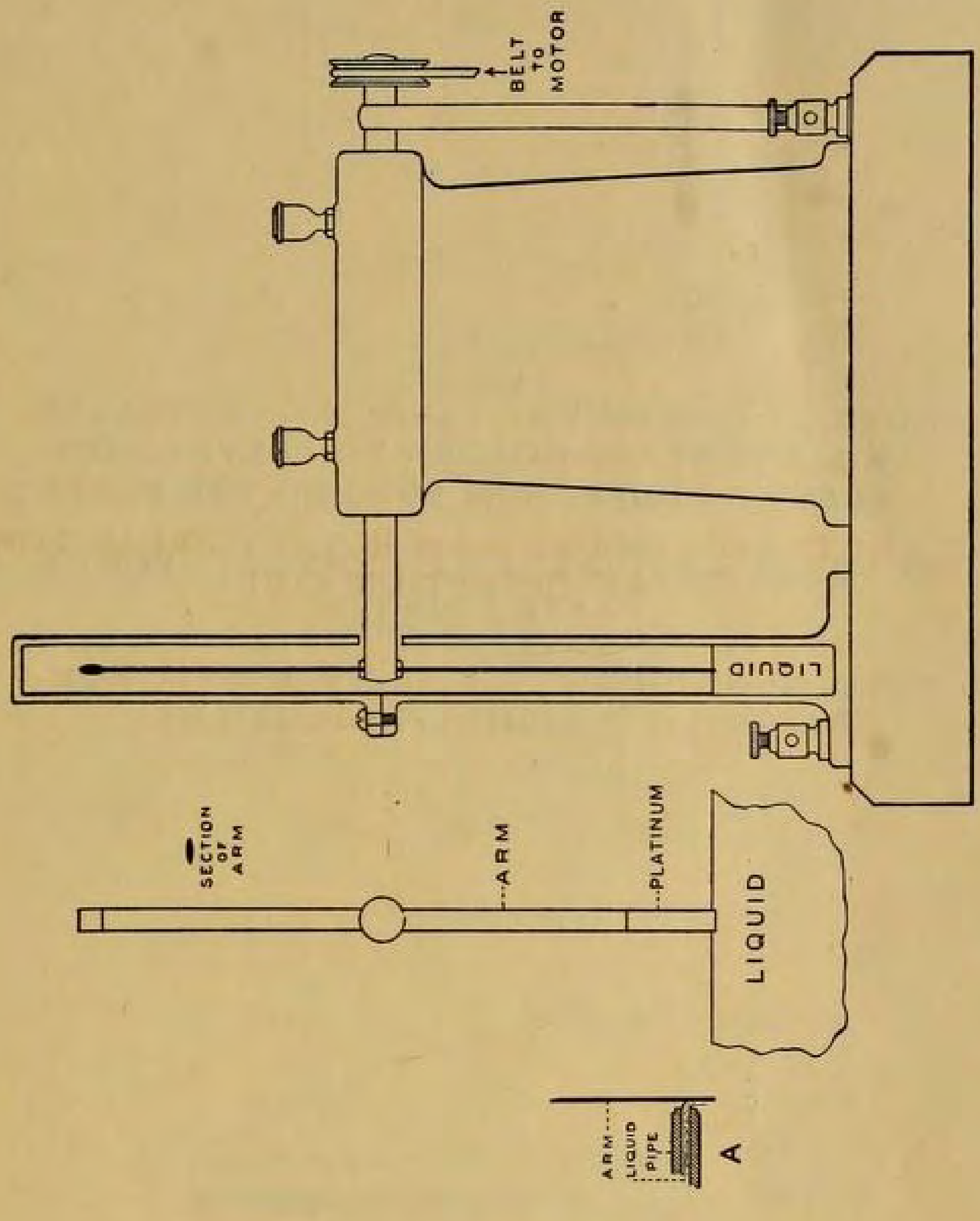
NOTES 116 B AND 117 — FIGURE 95 — A MOVABLE X-LIGHT EXAMINATION TABLE


A·W·L
LW

NOTE 116 C — FIGURE 96 — A NON-RADIABLE X-LIGHT TUBE BOX WITH A GRADUATED ARM



NOTE 120 — FIGURE 8 — A ROTARY BREAK FOR AN INDUCTION COIL


BELT
TO
MOTOR
LIQUID
SECTION
OF
ARM
ARM
PLATINUM
LIQUID
ARM
LIQUID
PIPE
A

NOTE 121 — FIGURE 5 — A NON-RADIABLE X-LIGHT PLATE-HOLDER TO PREVENT DIFFUSED X-LIGHT FROM FOGGING THE PLATE

NOTE 121 — FIGURE 6 — A SUPPORT FOR A PLATE-HOLDER

NOTE 121 — FIGURE 7 — A SECTION OF A NON-RADIABLE X-LIGHT PLATE-HOLDER

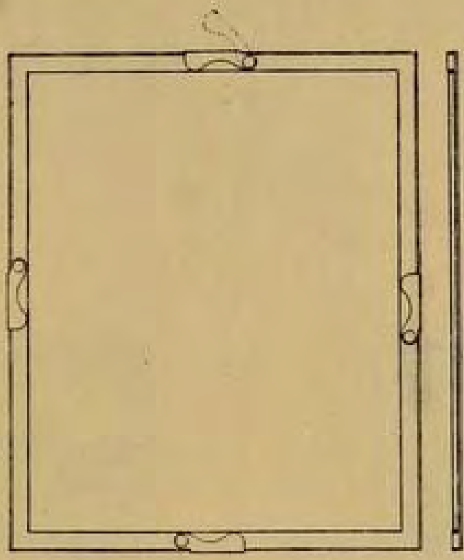


Figure 5

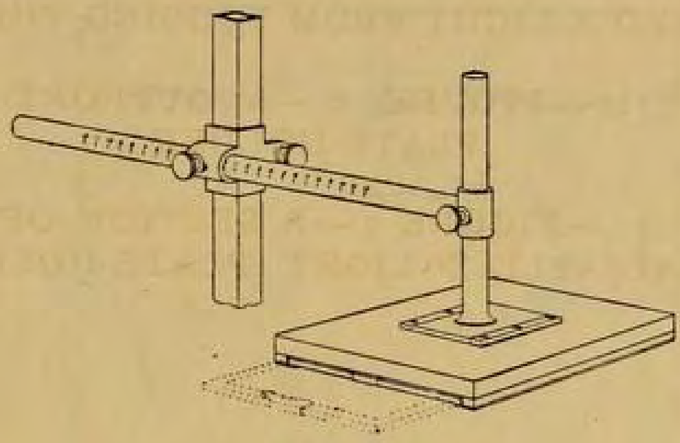


Figure 6

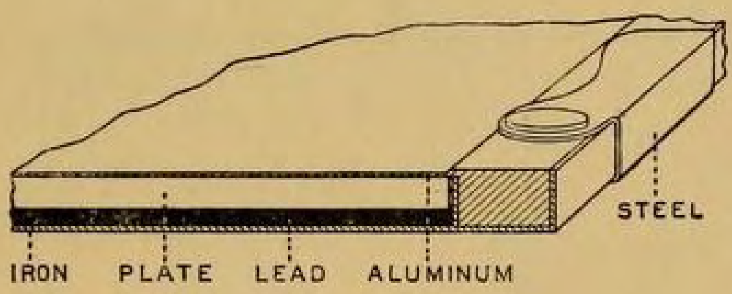


Figure 7

NOTE 137 — FIGURE 1 NOTE 137 — FIGURE 2

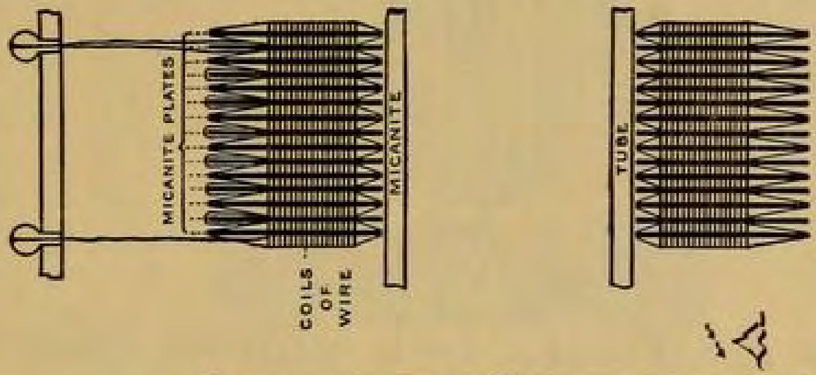


Figure 2

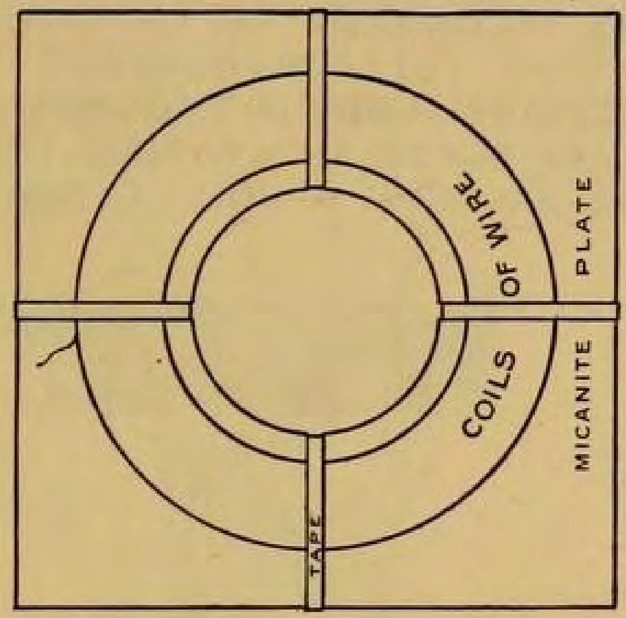
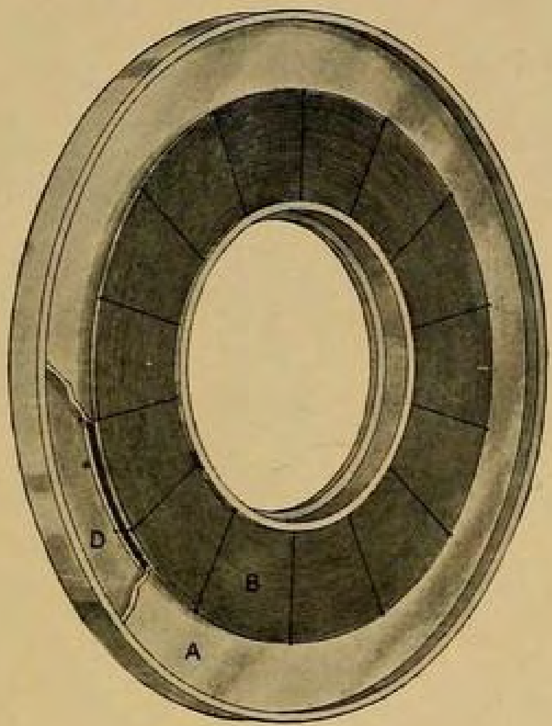


Figure 1

NOTE 137 — FIGURE 3 — A SECTION THROUGH THE SECONDARY OF AN INDUCTION COIL HAVING INTERCHANGEABLE SECONDARY SECTIONS SHOWING GLASS TRAYS. A, GLASS PLATE SEPARATING THE COILS OF ONE SECTION; B, COIL; C, MICANITE TUBE

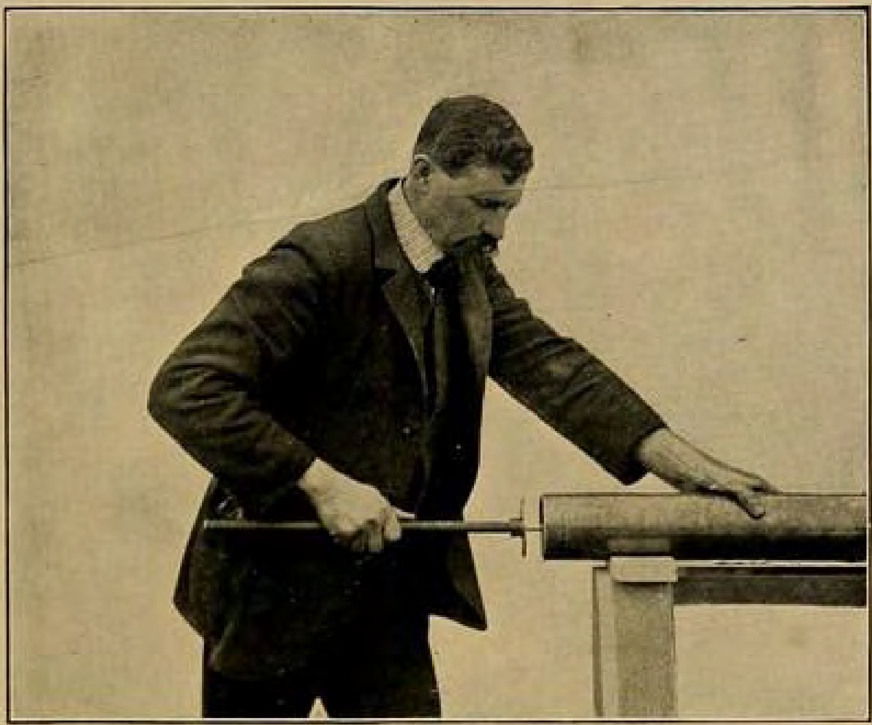
FIG. 3. SCALE $\frac{1}{2}$

NOTE 137 — FIGURE 4 — A GLASS CELL OF THE SECONDARY OF AN INTERCHANGEABLE SECTION INDUCTION COIL. TWO COILS MAKING ONE SECTION ARE SHOWN IMBEDDED IN INSULATING MATERIAL

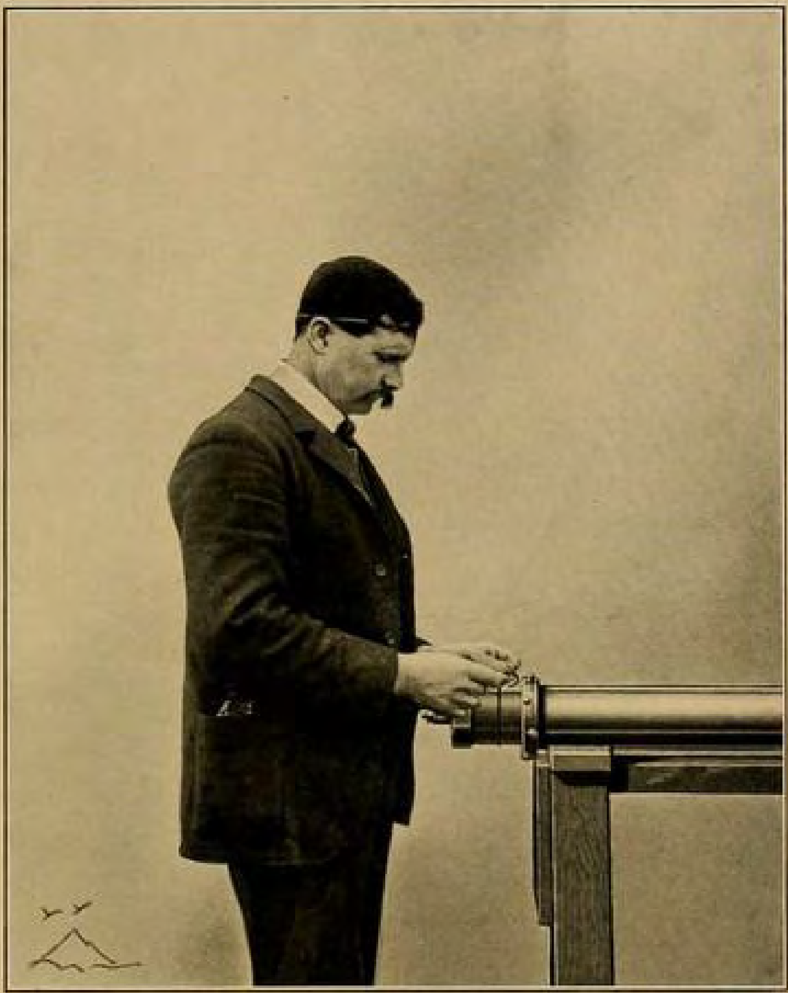

D
B
A

NOTE 137 — FIGURE 5 — METHOD OF PACKING THE IRON WIRE CORE

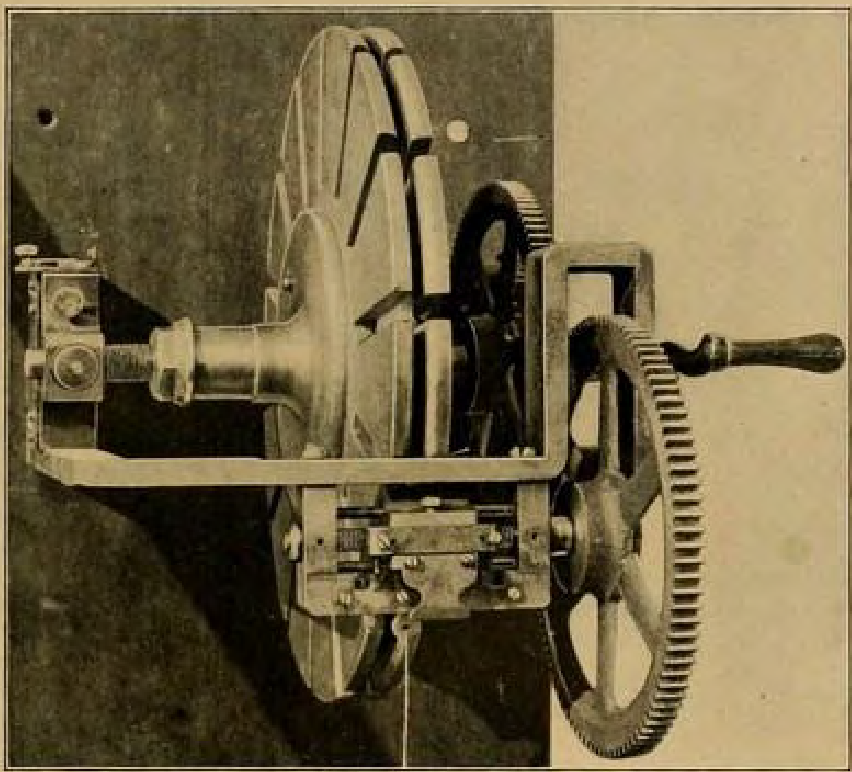
NOTE 137—FIGURE 6—PUSHING OUT THE CORE -OF THE PRIMARY OF AN INDUCTION COIL- FROM THE PACKING TUBE



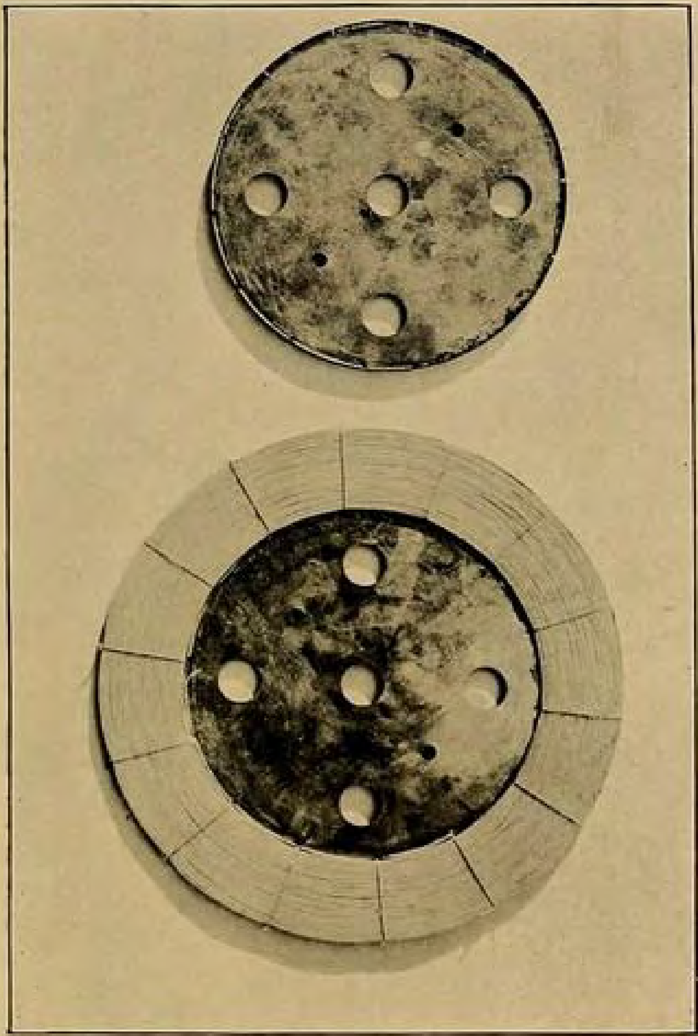
NOTE 137 — FIGURE 7 — TYING THE IRON CORE WIRES OF THE PRIMARY OF AN INDUCTION COIL



NOTE 137 — FIGURE 9 — A MACHINE FOR WINDING THE SECONDARY COILS OF AN INTERCHANGEABLE SECONDARY INDUCTION COIL

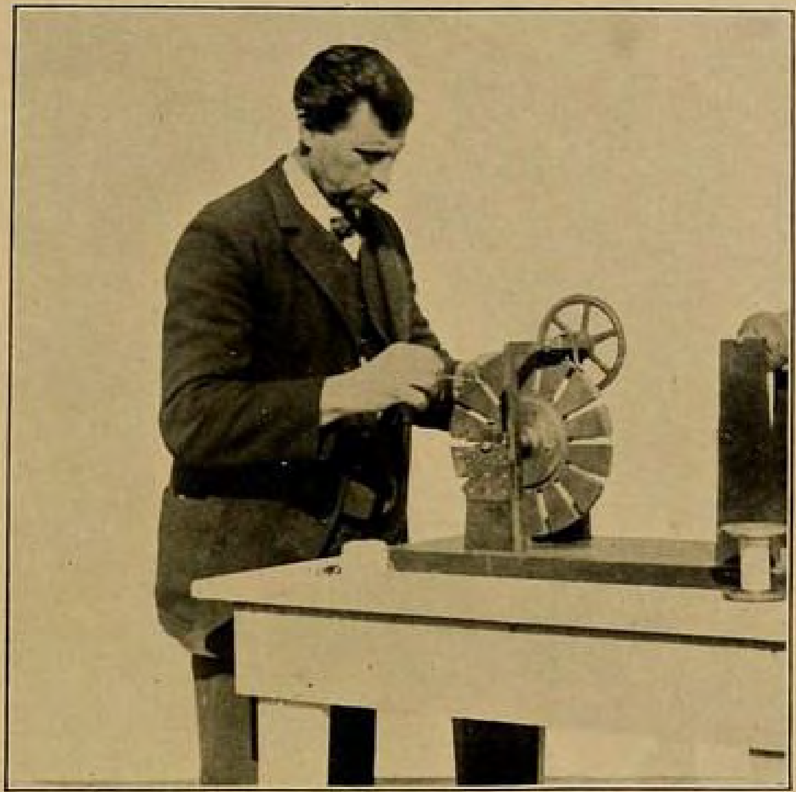


NOTE 137 — FIGURES 10 AND 14 — A METAL FORM WITH A FRESHLY WOUND COIL SHOWING THE METHOD OF TYING ONE OF THE SECONDARY COILS OF THE SECONDARY OF AN INDUCTION COIL HAVING INTERCHANGEABLE SECONDARY SECTIONS



NOTE 137 — FIGURE 11 — WINDING A SECONDARY COIL, FORMING ONE HALF OF A SECTION OF THE SECONDARY OF AN INDUCTION COIL WITH INTERCHANGEABLE SECONDARY SECTIONS

NOTE 137 — FIGURE 12 — TYING A SECONDARY COIL AFTER WINDING, THE COIL FORMING ONE HALF OF A SECTION OF THE SECONDARY OF AN INDUCTION COIL HAVING INTERCHANGEABLE SECTIONS IN THE SECONDARY



NOTE 137—FIGURE 13—SHAFT OF THE WINDING MACHINE REMOVED FROM ITS BEARINGS WITH ONE FLANGE TAKEN OFF TO SHOW A COIL FORMING ONE HALF OF A SECTION OF THE SECONDARY OF AN INDUCTION COIL HAVING INTERCHANGEABLE SECTIONS IN THE SECONDARY

NOTE 137—FIGURE 16—A DIPPING-ARBOR WITH ONE FLANGE REMOVED, SHOWING ONE COIL PARTLY REMOVED AND OTHERS PLACED TO ILLUSTRATE THE RIGIDITY PRODUCED BY DIPPING

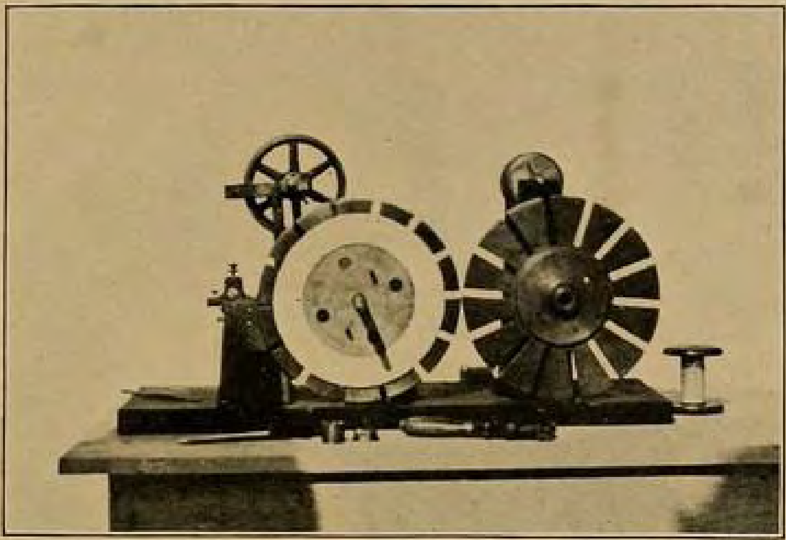


Figure 13

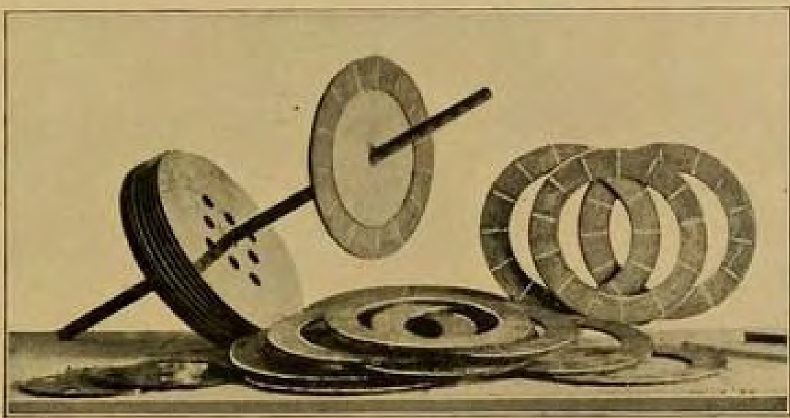
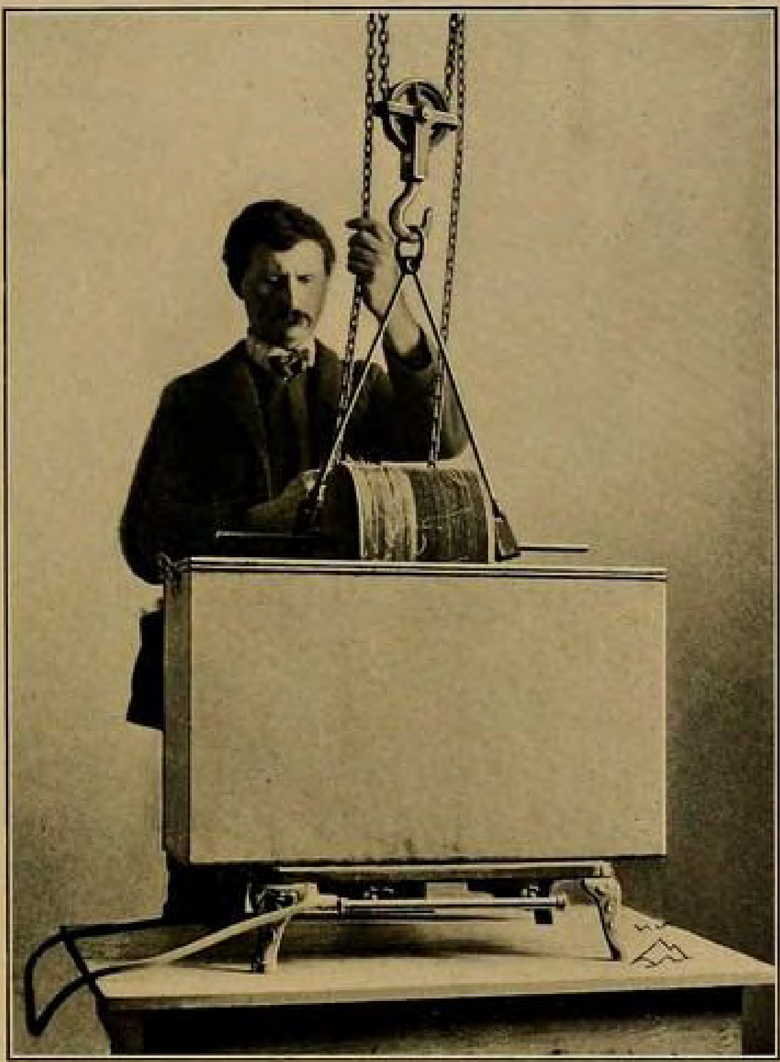


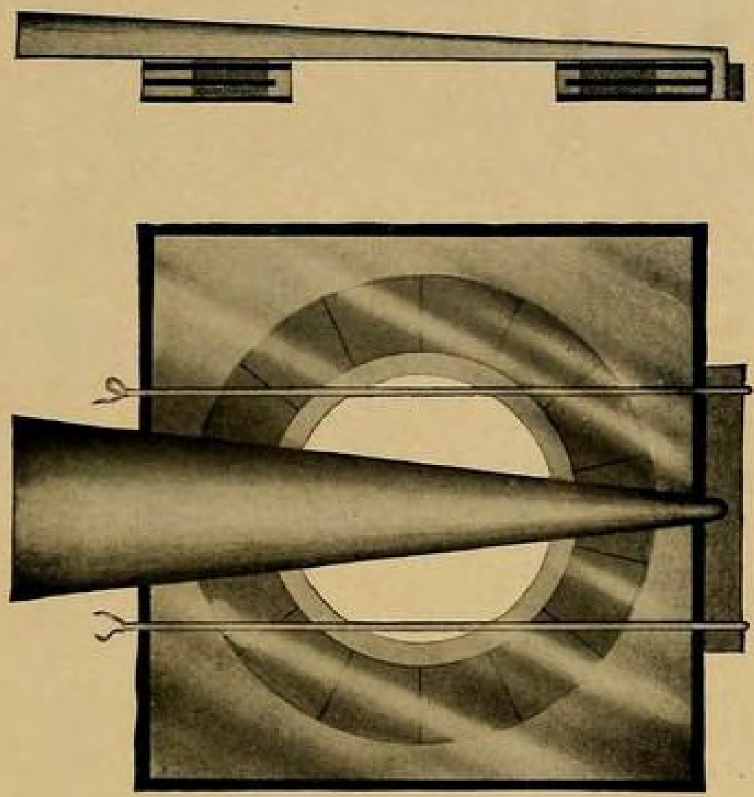
Figure 16

NOTE 137 — FIGURE 15 — DIPPING SECTIONS OF THE SECONDARY OF THE INTERCHANGEABLE SECONDARY INDUCTION COIL

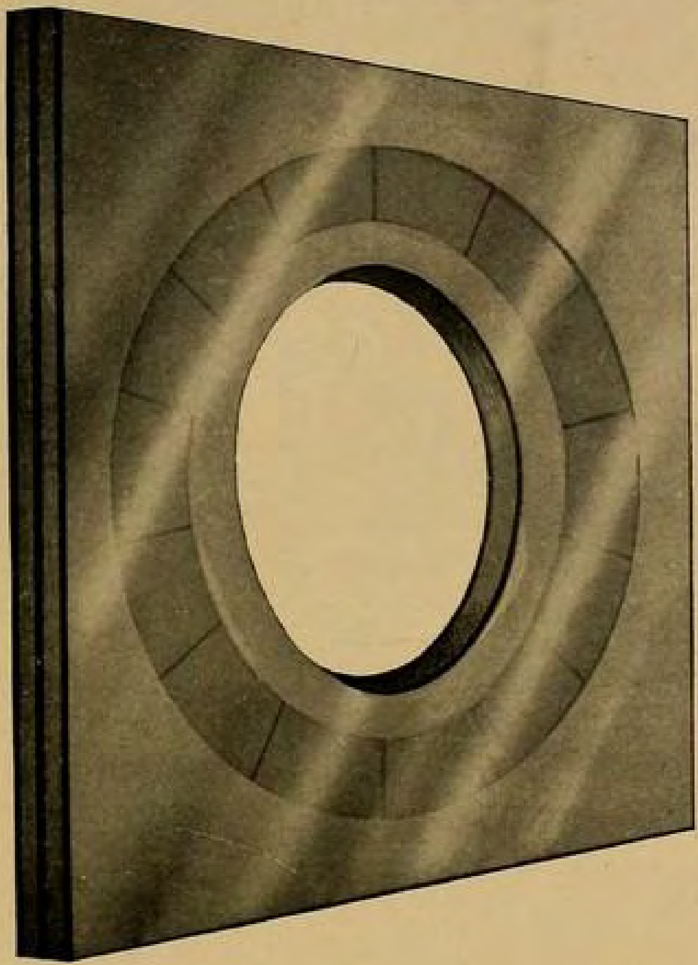


NOTE 137 — FIGURE 17 — ELEMENTS OF ONE SECTION OF THE SECONDARY WINDING OF 70-CENTIMETRE COIL HAVING INTERCHANGEABLE SECTIONS IN THE SECONDARY

NOTE 137 — FIGURE 18 — A METHOD OF CASTING OZOKERITE AROUND ONE PAIR OF COILS, FORMING A SECTION OF AN INDUCTION COIL WITH INTERCHANGEABLE SECTIONS IN THE SECONDARY



NOTE 137 — FIGURE 19 — A FINISHED SECTION OF THE SECONDARY OF AN INDUCTION COIL HAVING INTERCHANGEABLE SECTIONS IN THE SECONDARY



NOTE 137 — FIGURE 8 — A GENERAL VIEW OF THE PRIMARY OF A 70-CENTIMETRE COIL, CUT AWAY TO SHOW THE INTERIOR

NOTE 137 — FIGURE 20 — PERSPECTIVE VIEW OF 70-CENTIMETRE INTERCHANGEABLE SECONDARY INDUCTION COIL

NOTE 137 — FIGURE 21 — A PERSPECTIVE VIEW OF A 70-CENTIMETRE INTERCHANGEABLE SECONDARY INDUCTION COIL SHOWING THE DIVISION BOXES SEPARATED

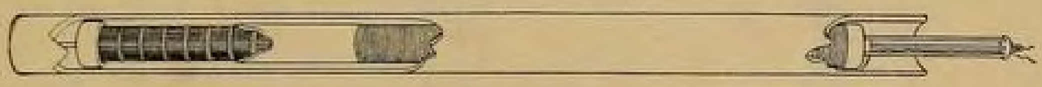


Figure 8

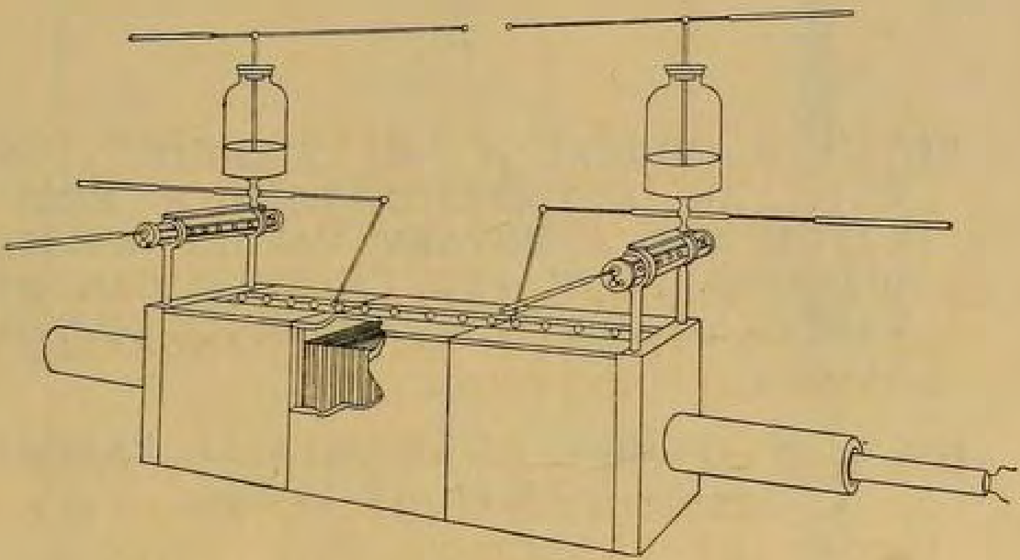


Figure 20

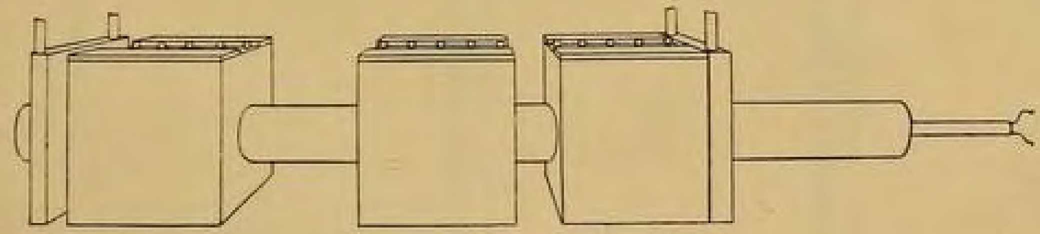


Figure 21

NOTE 138 — FIGURE 1 — AN X-LIGHT TUBE WITH AN AUTOMATIC VACUUM REGULATOR AND A ROTARY TARGET WHOSE DISTANCE FROM THE CATHODE CAN BE VARIED TO SUIT THE RESISTANCE OF THE TUBE

NOTE 138 — FIGURE 2 — ADJUSTABLE TARGET FOR AN X-LIGHT TUBE

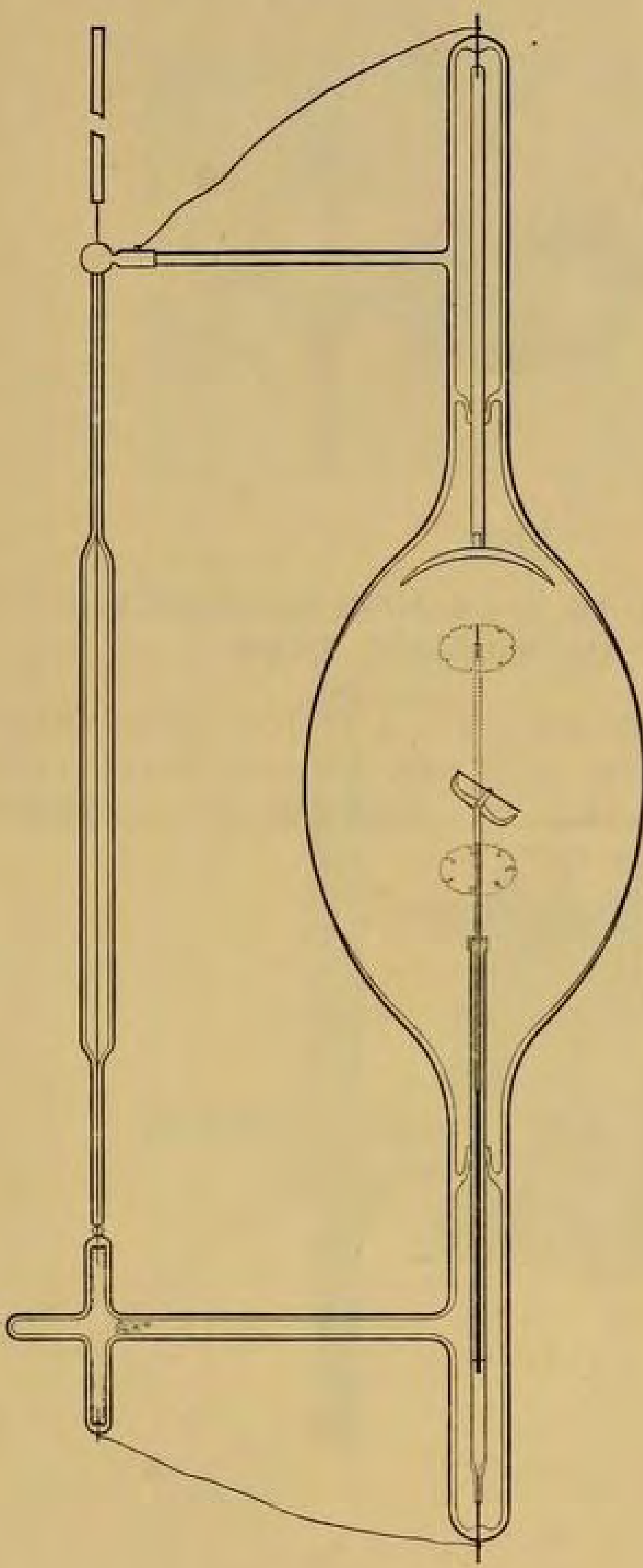


Figure 1

Figure 2

NOTE 139 — FIGURE 1 — A NON-RADIABLE BOX FOR AN X-LIGHT TUBE

NOTE 139 — FIGURE 2 — A NON-RADIABLE X-LIGHT TUBE BOX SHOWING THE TOP BEING REMOVED TO ALLOW THE TUBE TO BE TAKEN OUT

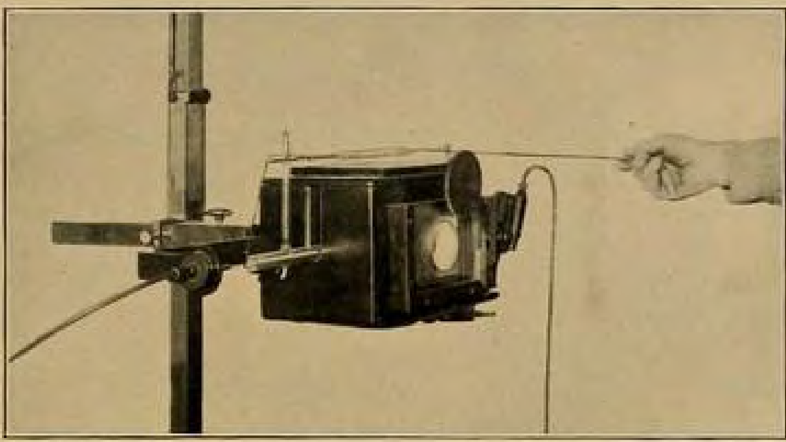


Figure 1

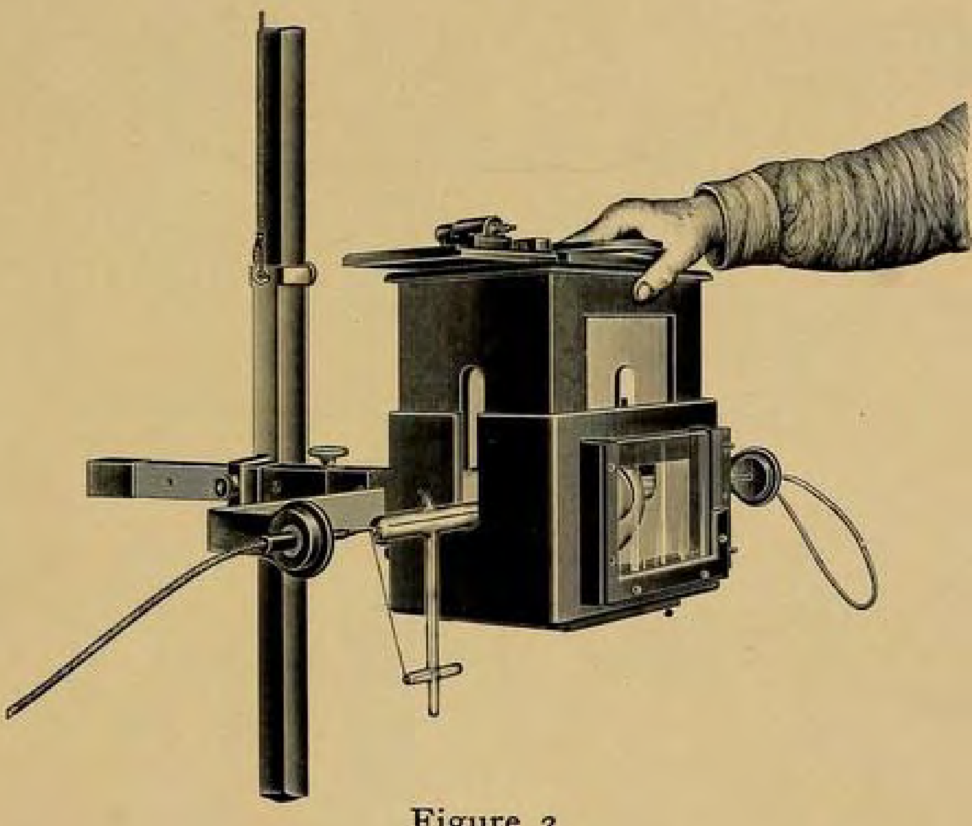
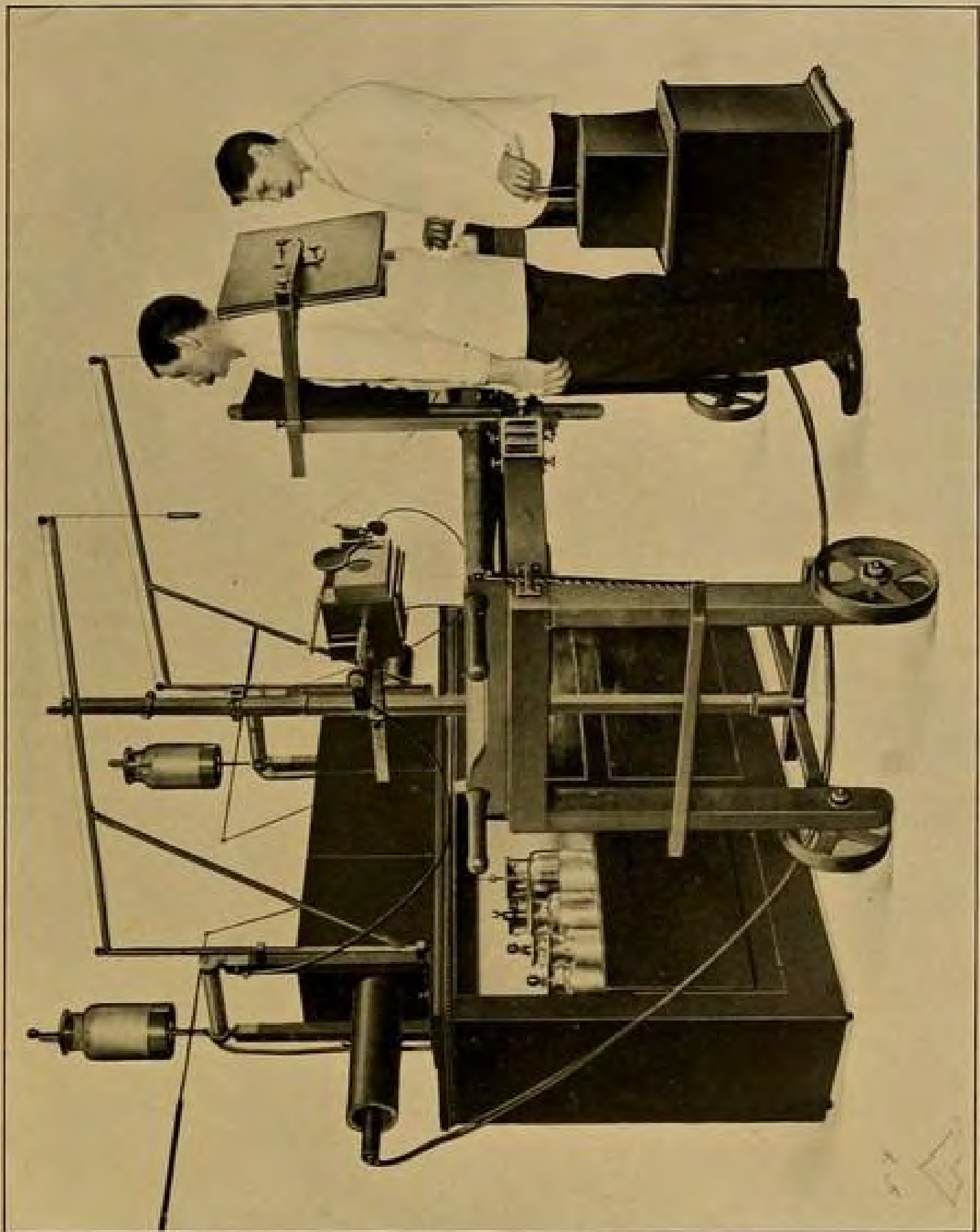
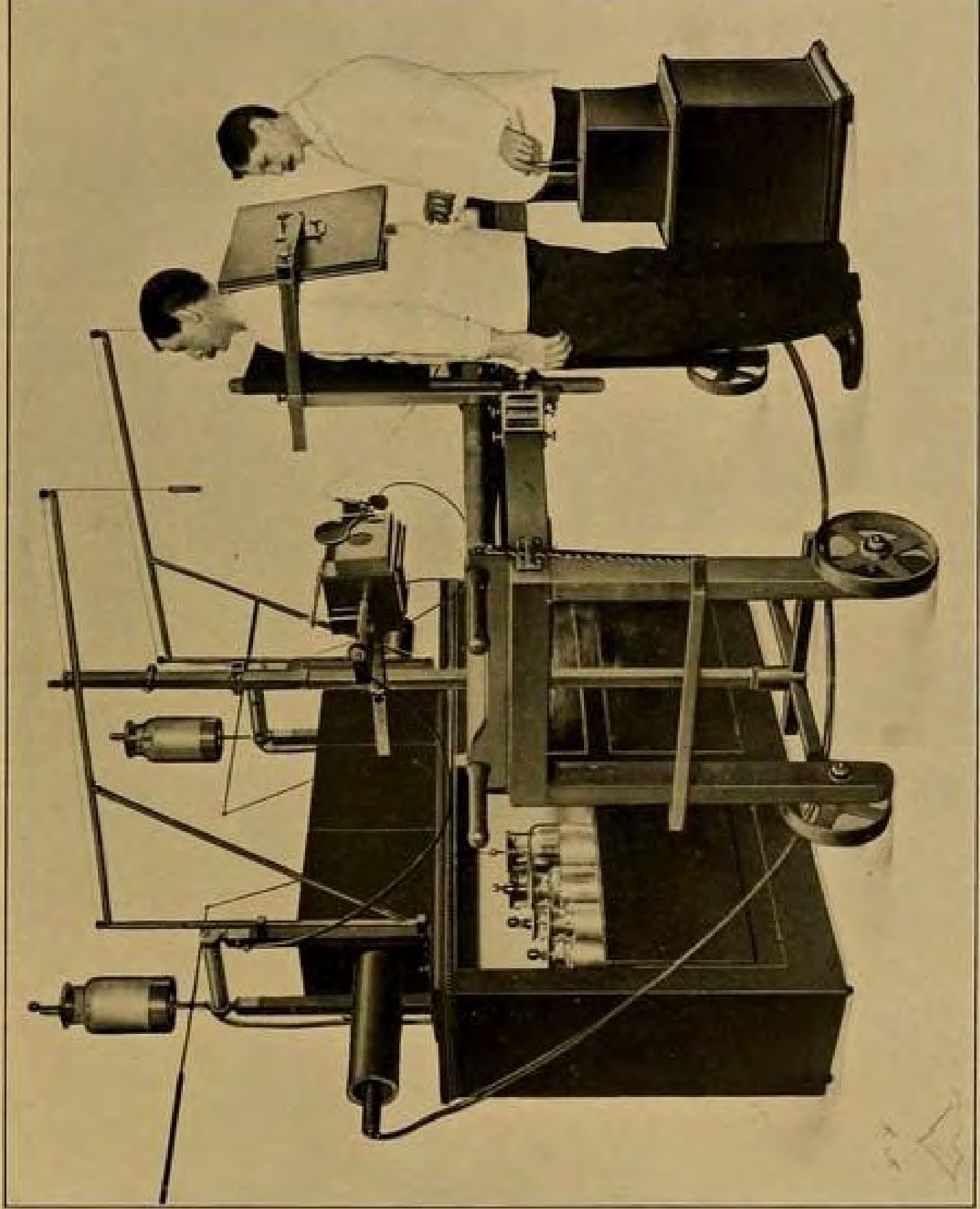


Figure 2

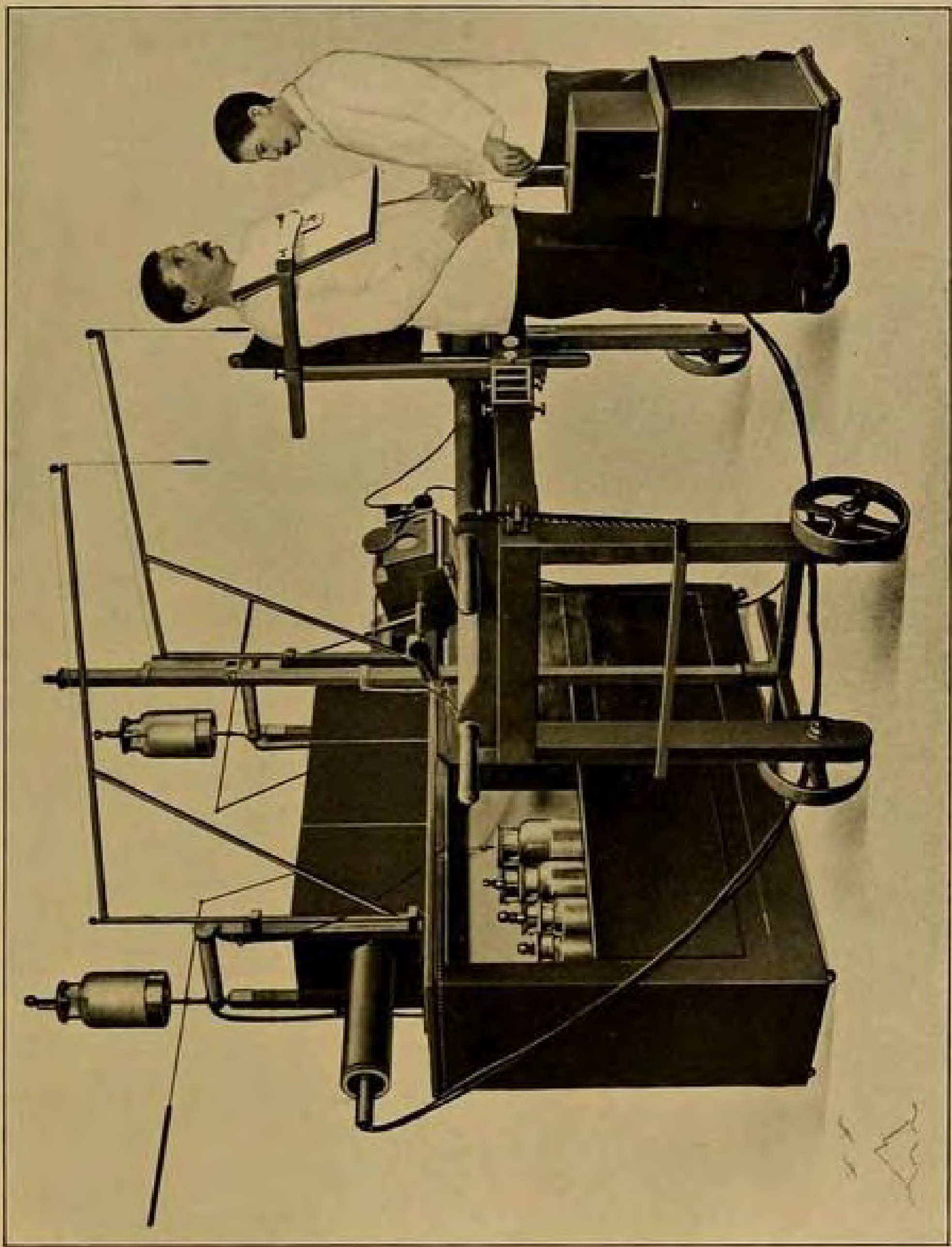
NOTE 140 — FIGURE 4 — PHOTOGRAPHING A CHEST WITH THE SOURCE OF X-LIGHT IN FRONT



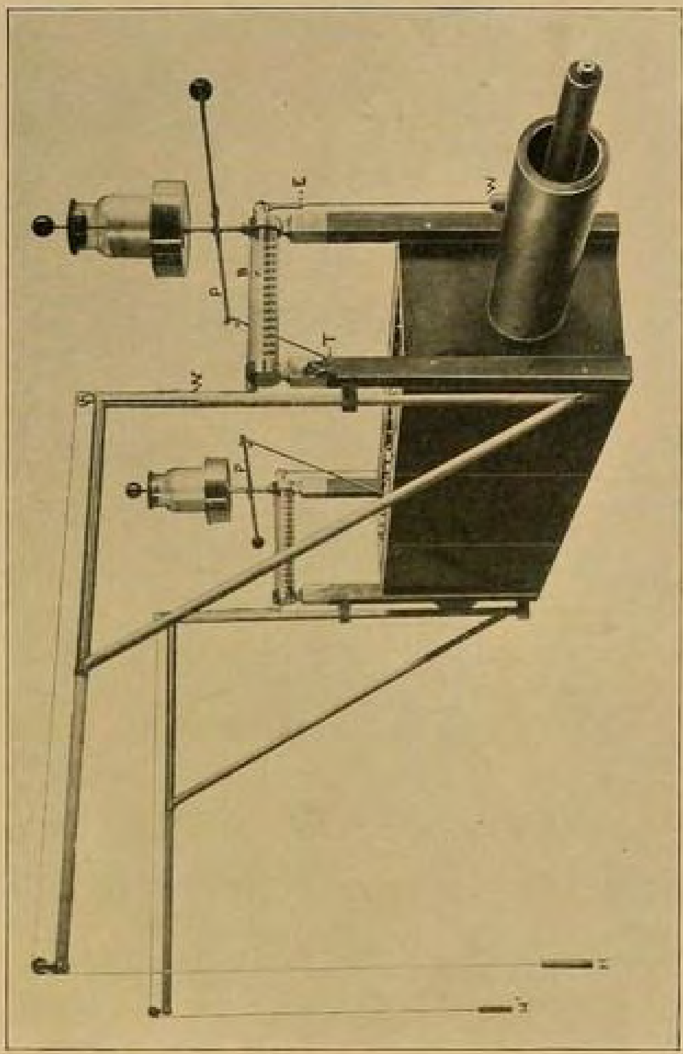
NOTE 140 — FIGURE 4 — PHOTOGRAPHING A CHEST WITH THE SOURCE OF X-LIGHT IN FRONT



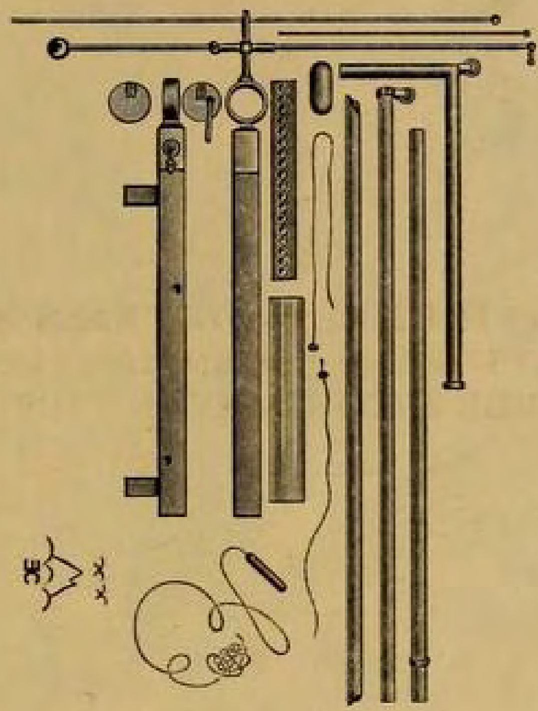
NOTE 140—FIGURE 5—PHOTOGRAPHING A CHEST WITH THE PATIENT UPRIGHT AND THE SOURCE OF X-LIGHT BEHIND



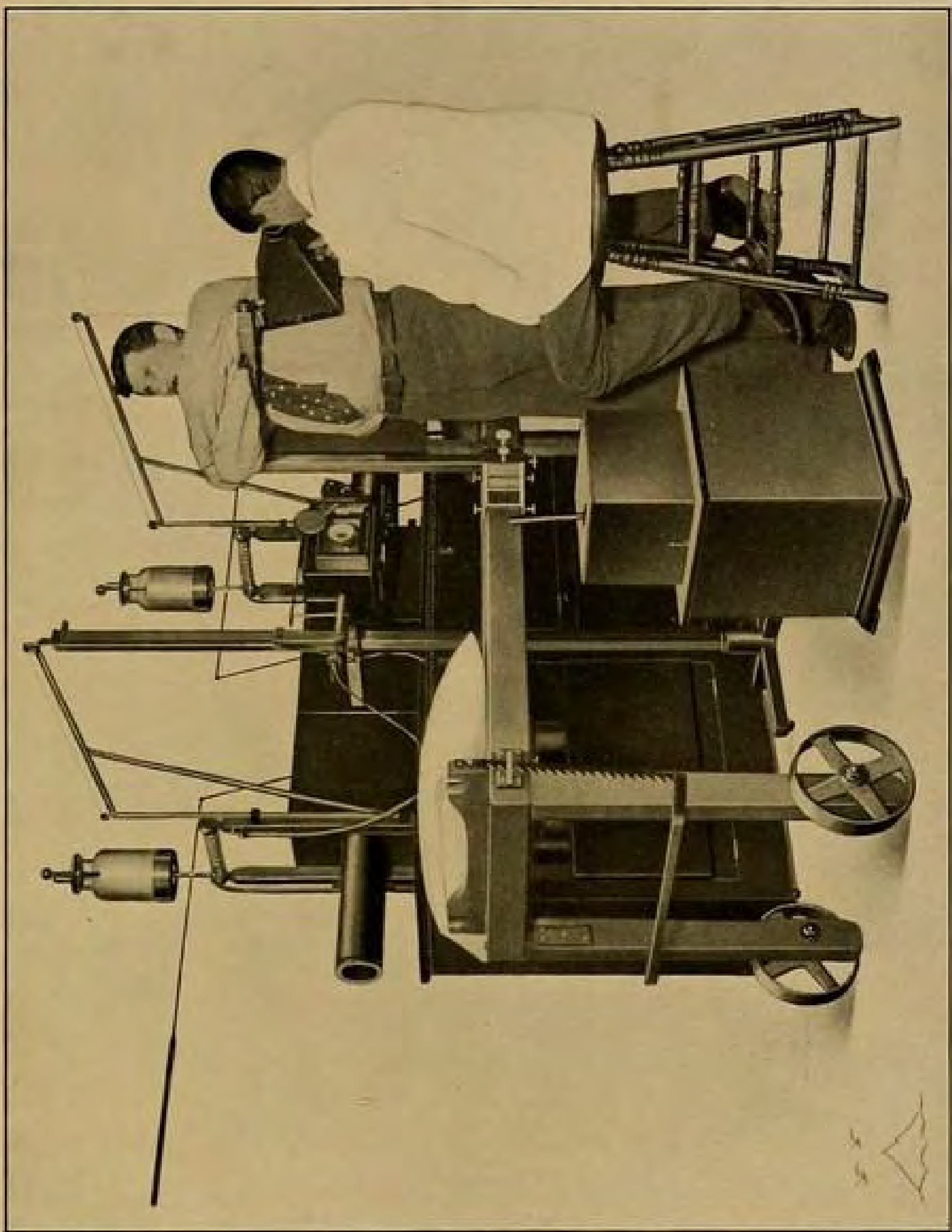
NOTE 140 — FIGURE 6 — INTERCHANGEABLE SECONDARY INDUCTION COIL ARRANGED FOR CRYPTOSCOPIC EXAMINATIONS



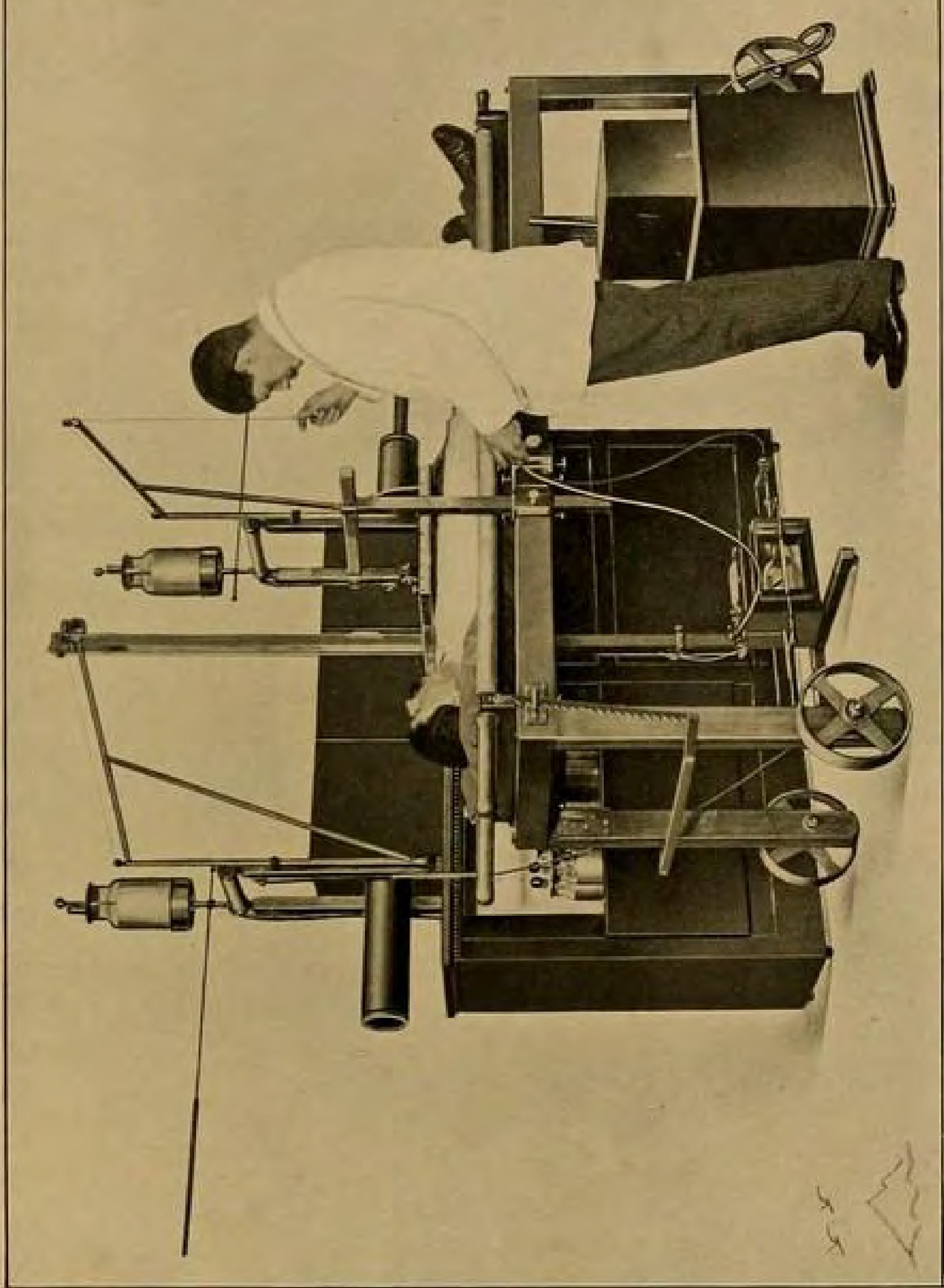
NOTE 140—FIGURE 7—DETAILS OF THE SPARK-GAPS OF A 71-CENTIMETRE INTERCHANGEABLE SECONDARY INDUCTION COIL



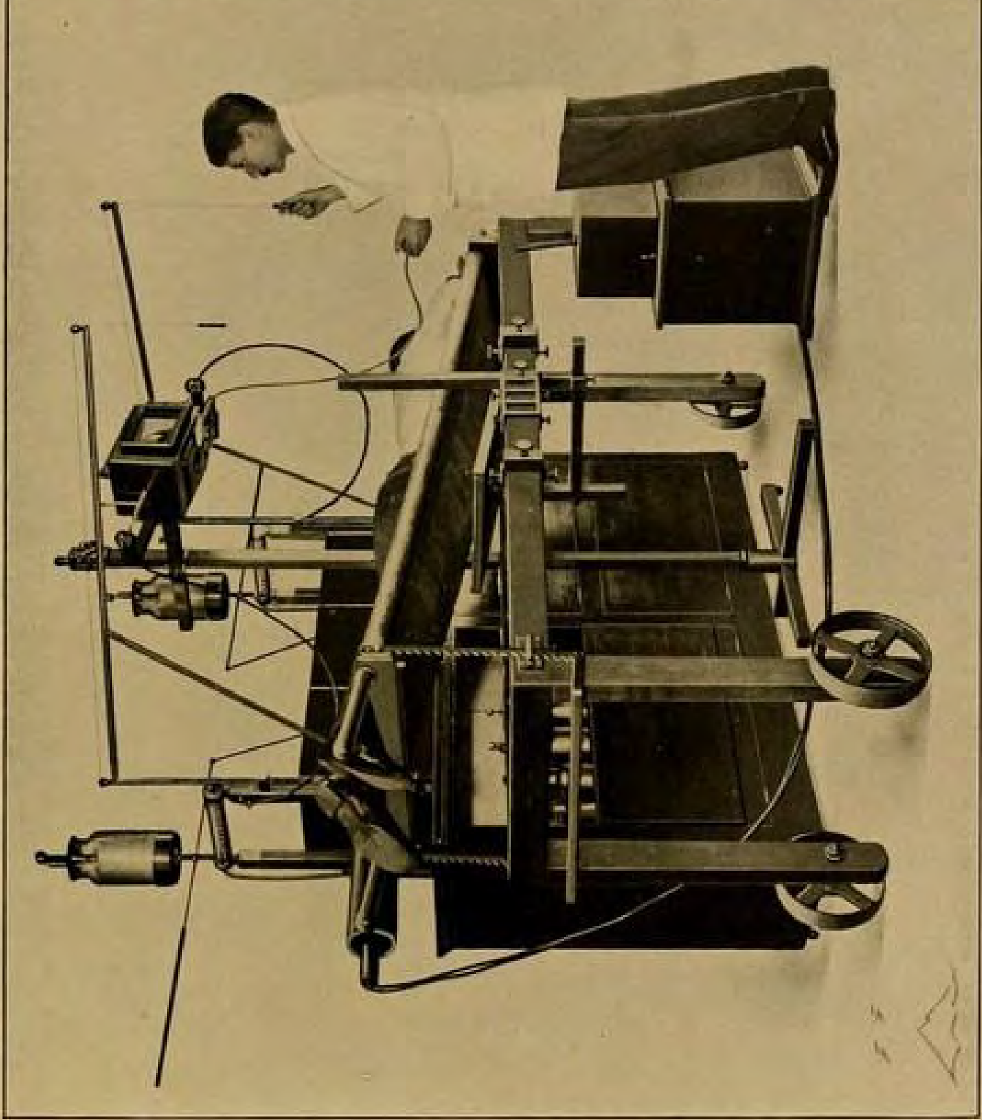
NOTE 140 — FIGURE 8 — EXAMINING THE HEART FROM ONE SIDE. WILLIAMS TRIANGLE



NOTE 140 — FIGURE 8½ — PHOTOGRAPHING THE CHEST BY X-LIGHT WITH THE X-LIGHT TUBE BELOW. SHOWING THE USE OF AN INSTANTANEOUS SHUTTER

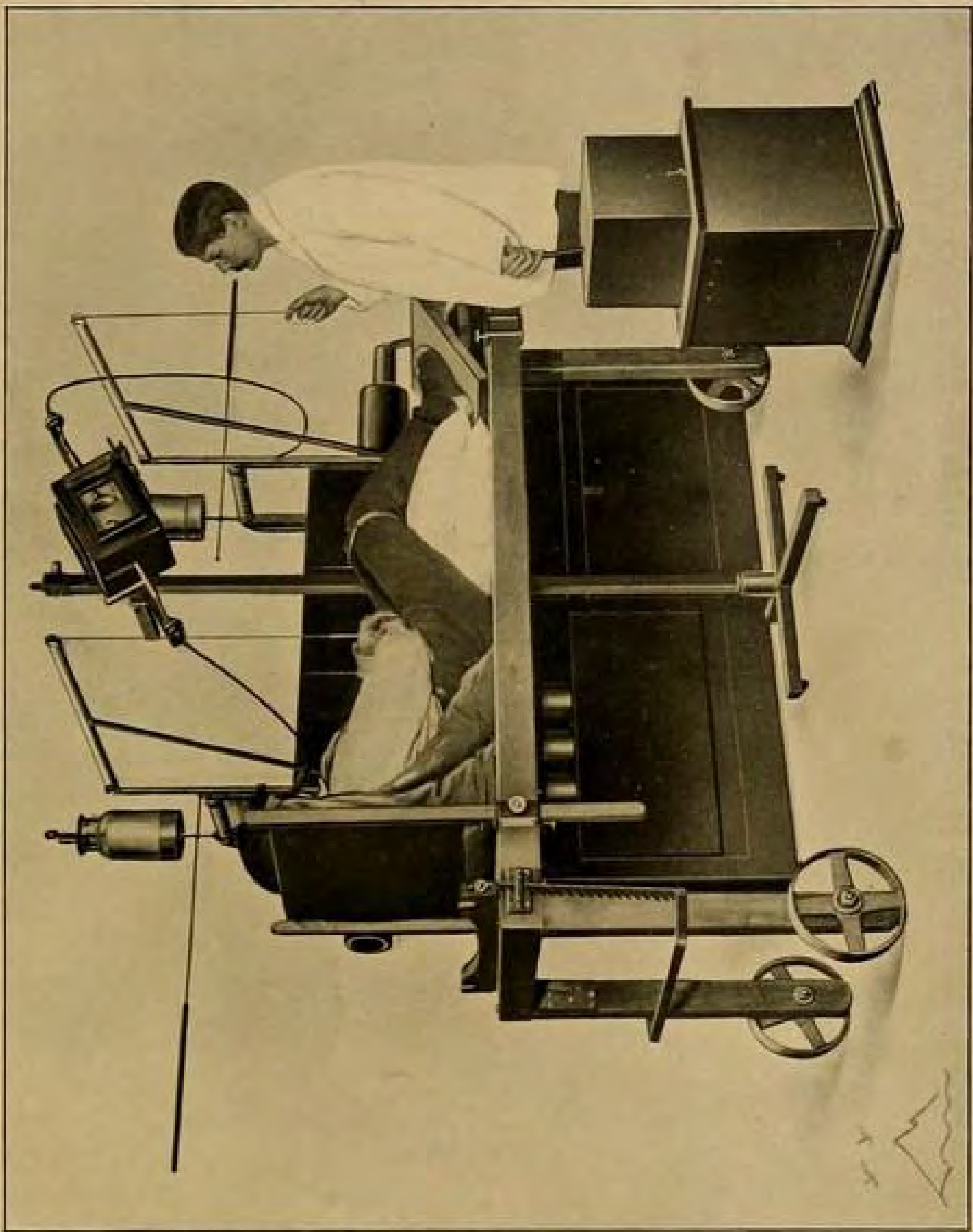


NOTE 140 — FIGURE 9 — POSITION FOR PHOTOGRAPHING A STONE IN THE BLADDER

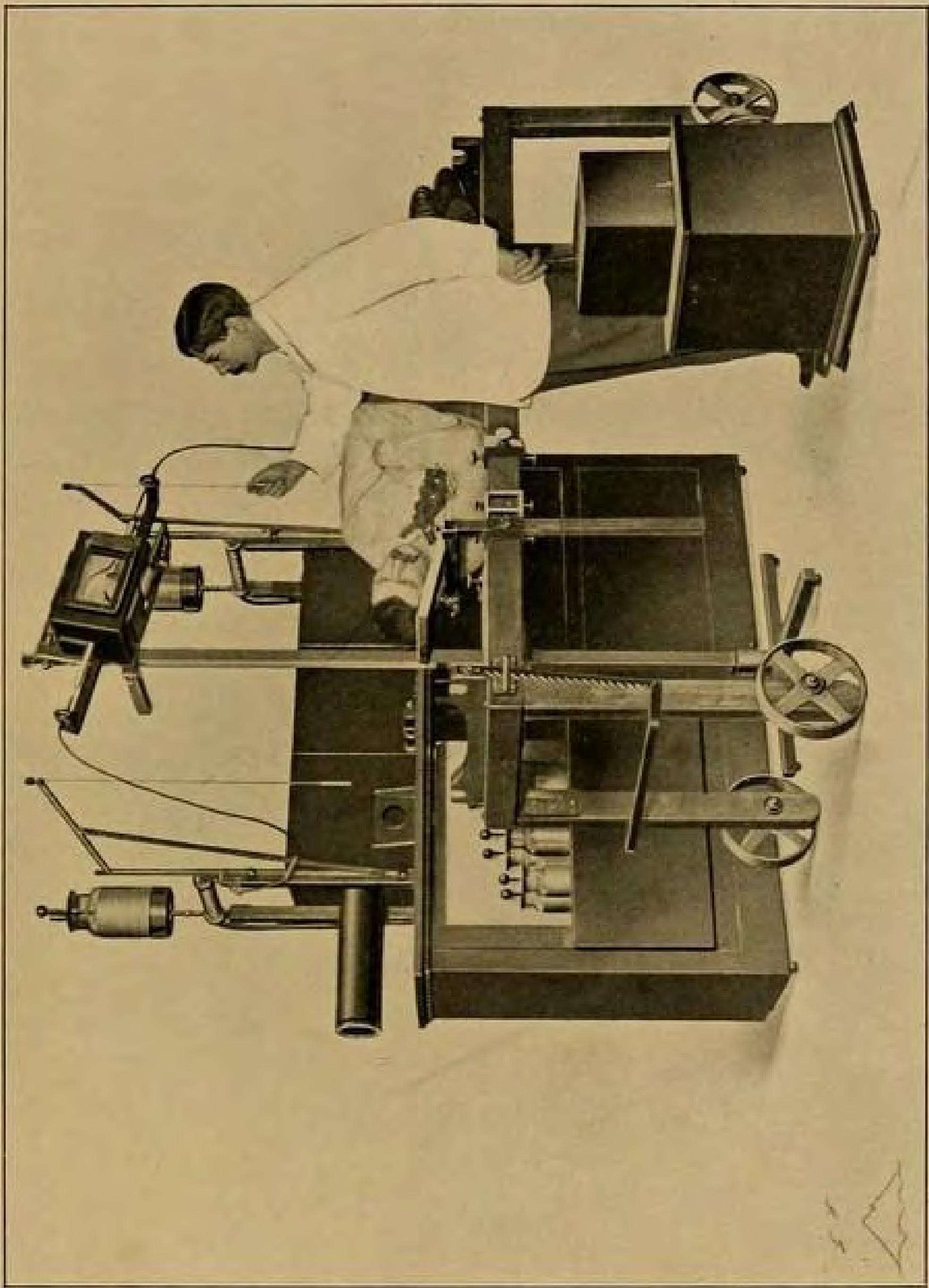


NOTE 140 — FIGURE 10 — PHOTOGRAPHING THE FEET WITH THE SOURCE OF X-LIGHT ABOVE

Plate 86



NOTE 140 — FIGURE 11 — PHOTOGRAPHING THE HEAD WITH THE X-LIGHT TUBE ABOVE



NOTE 139 — FIGURE 3 — SHOWING AN INSULATING COLLAR AND A SPIRAL SPRING CONNECTION BETWEEN THE X-LIGHT TUBE AND THE COIL

NOTE 140 — FIGURE 11½ — A BACK SUPPORT FOR AN X-LIGHT EXAMINATION TABLE

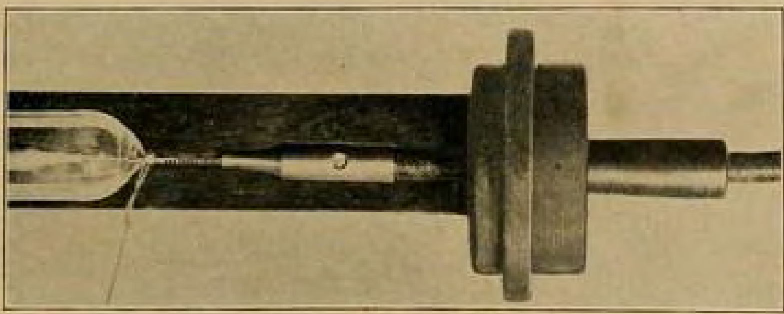


Figure 3

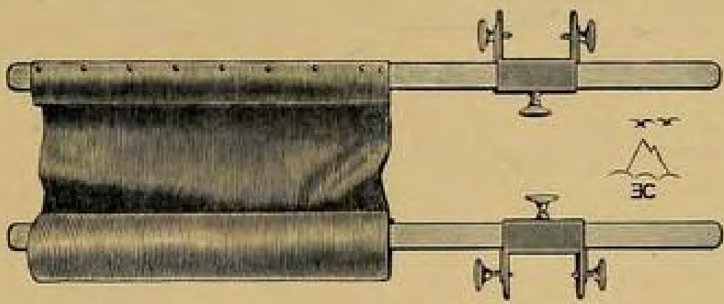
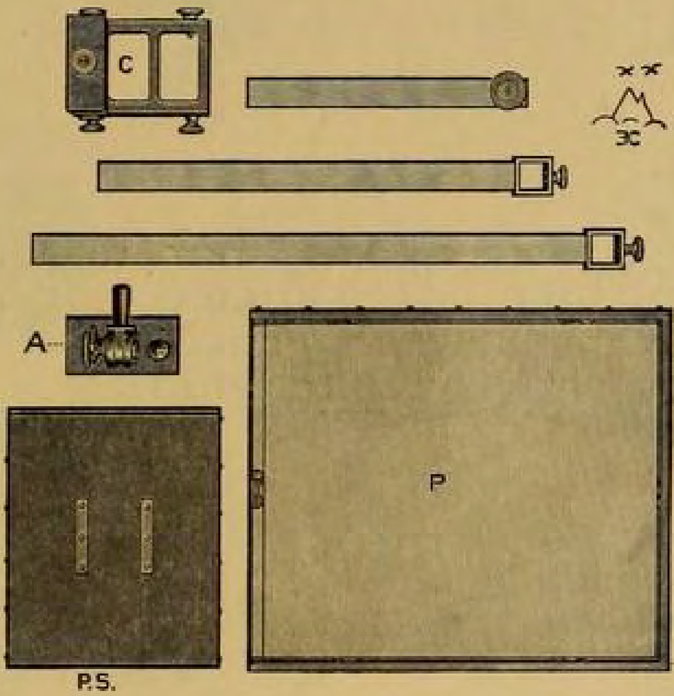


Figure 11½

NOTE 140—FIGURE 12—APPARATUS FOR SUPPORTING A PHOTOGRAPHIC PLATE


C
ЭC
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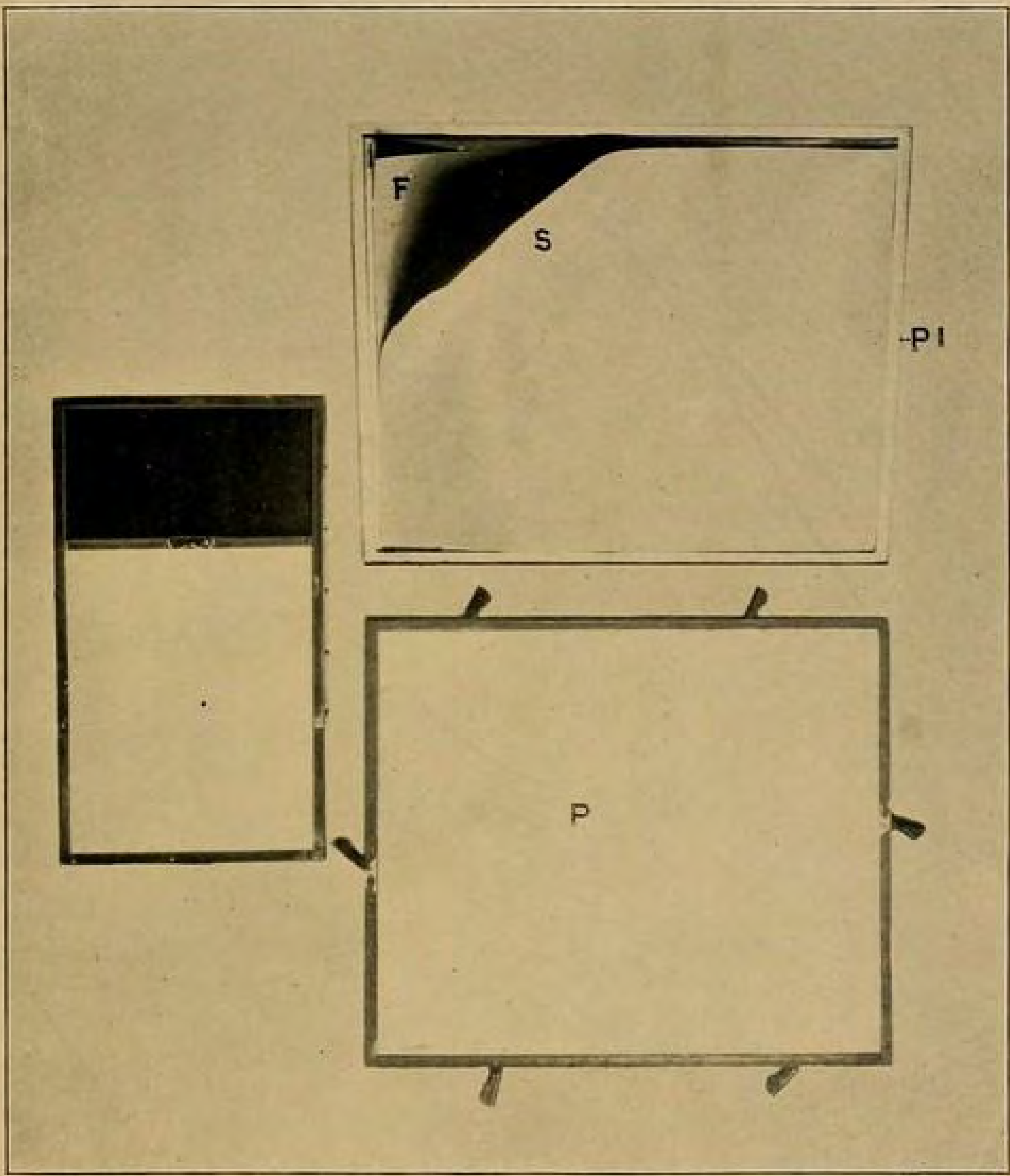
P.S.

NOTE 140 — FIGURE 14 — DETAILS OF A NON-RADIABLE PLATE-HOLDER FOR PREVENTING DIFFUSED X-LIGHT FROM FOGGING THE PHOTOGRAPHIC PLATE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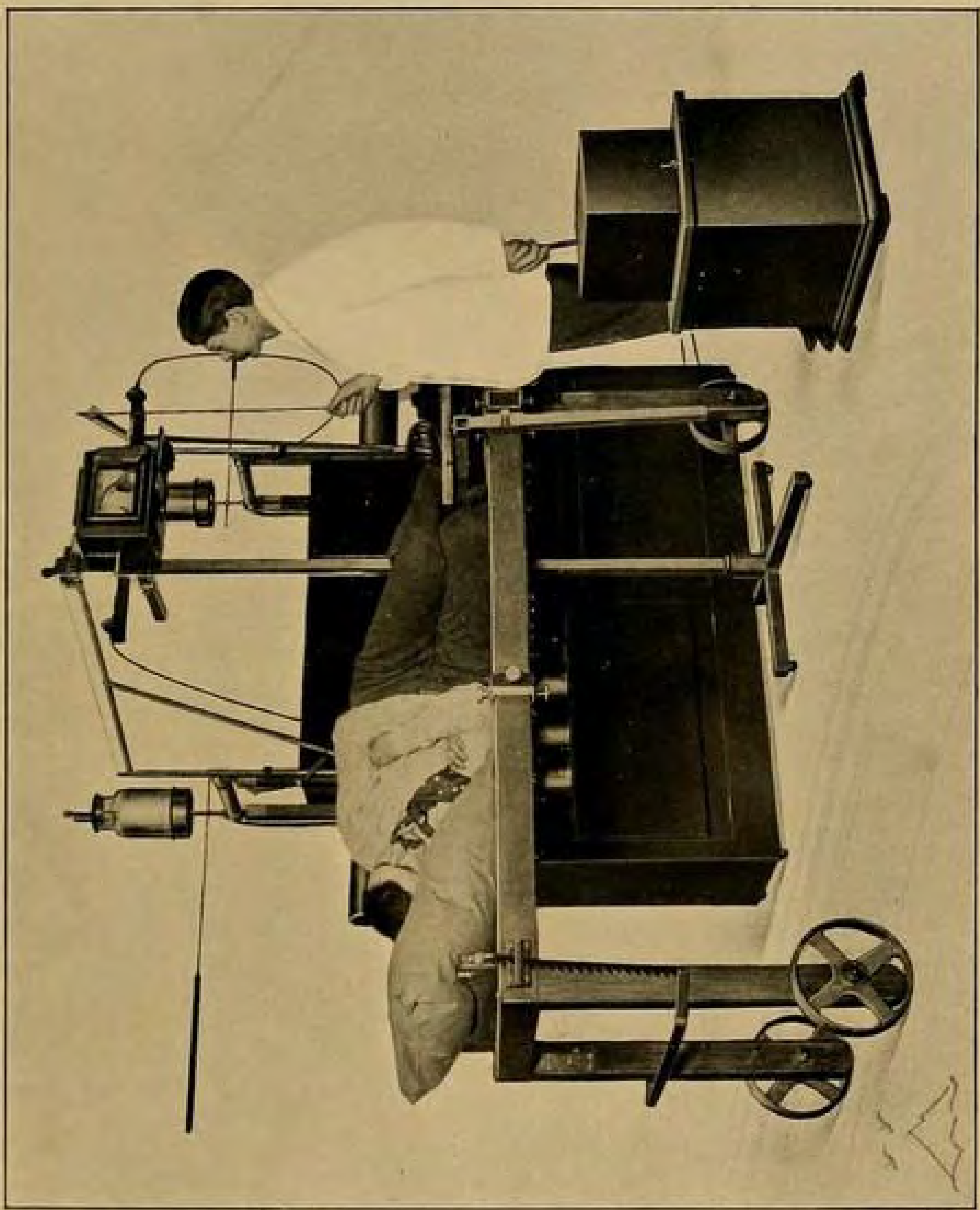
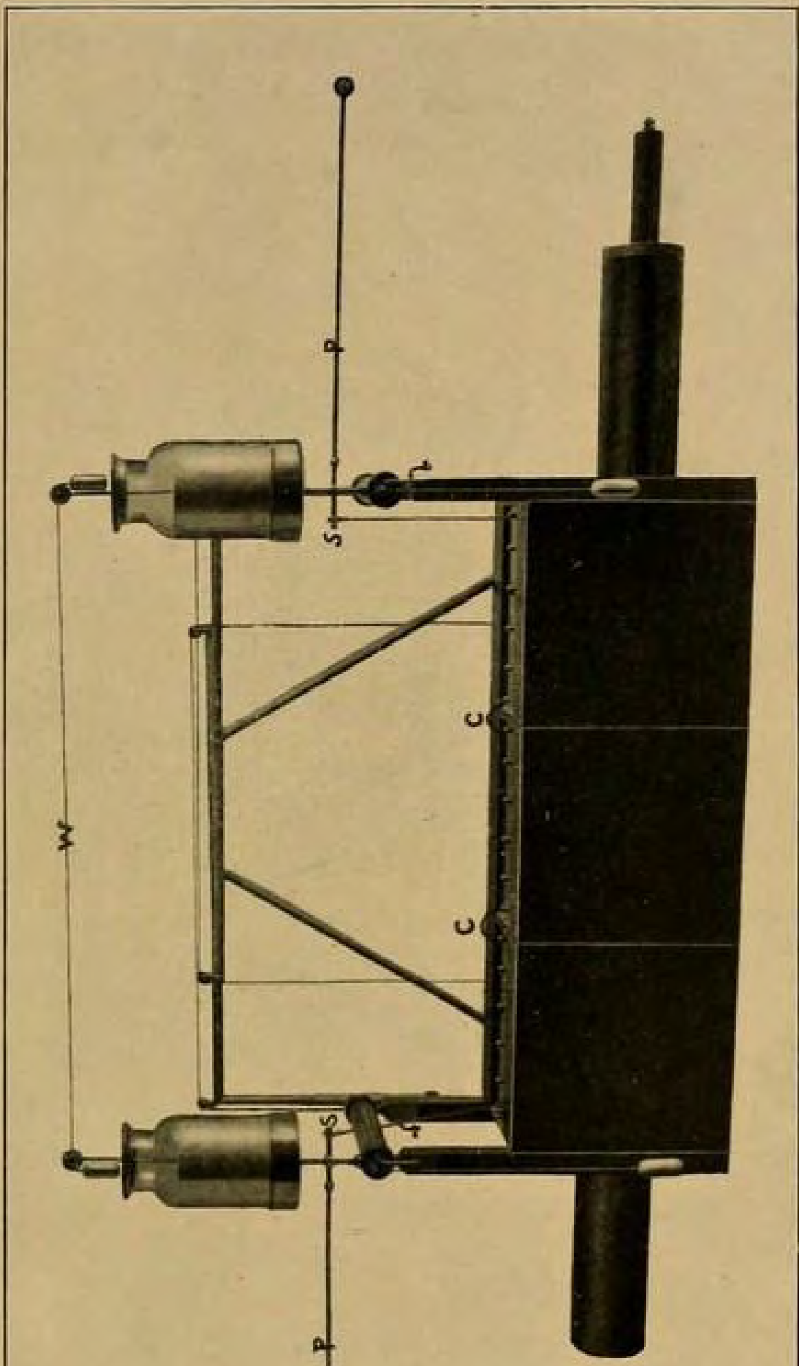
P1
P

NOTE 140 — FIGURE 15 — PHOTOGRAPHING AN ANKLE WITH THE SOURCE OF X-LIGHT ABOVE

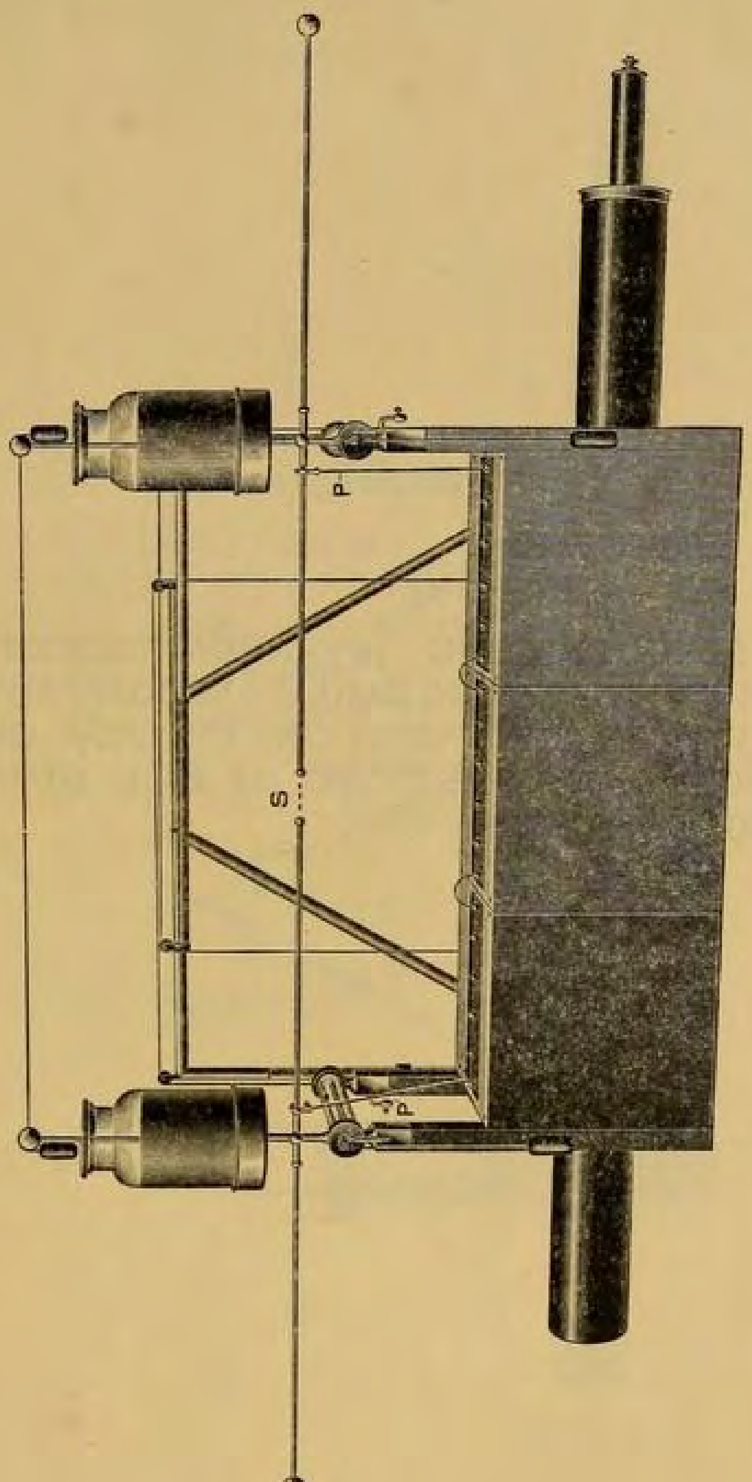


NOTE 141 — FIGURE 16 — RODS ARRANGED TO GIVE THE FULL POTENTIAL OF THE COIL

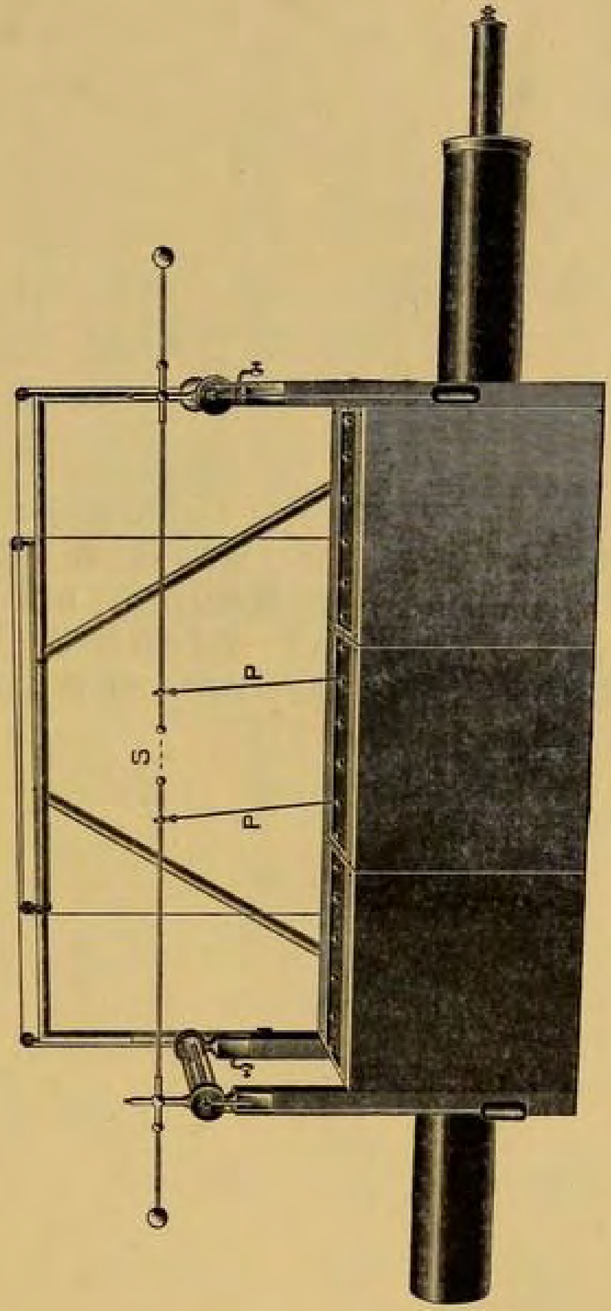
Plate 92



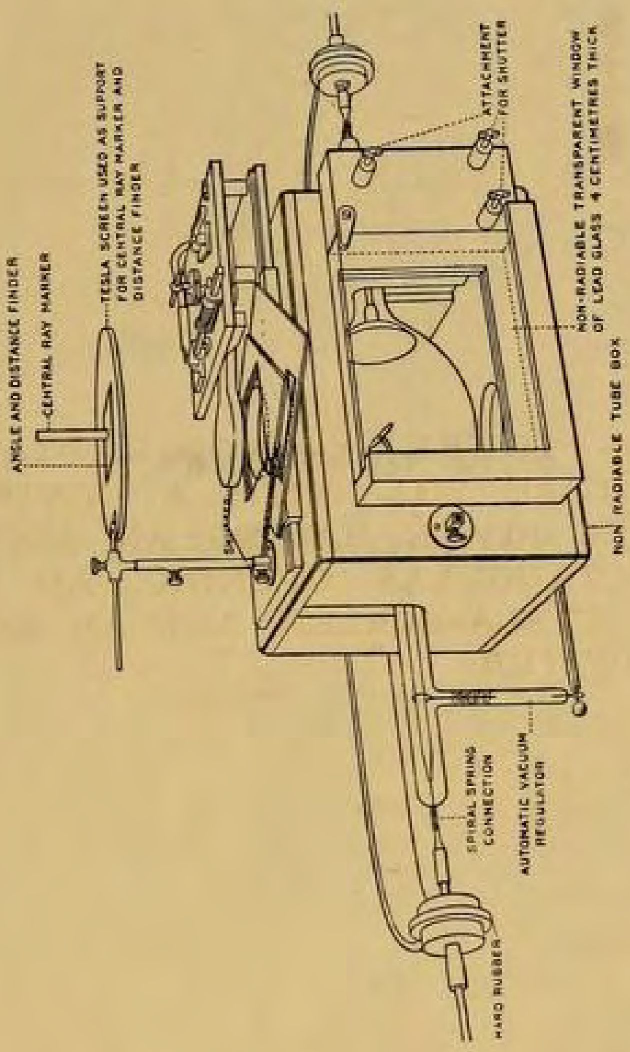
NOTE 141 — FIGURE 17 — ARRANGEMENT OF AN INTERCHANGEABLE SECONDARY INDUCTION COIL WITH ALL THE SECTIONS OF THE SECONDARY IN USE, GIVING THE FULL POTENTIAL OF THE COIL, AND WITH THE SPARK-GAPS ARRANGED TO SHUNT THE CURRENT, WHEN THE STARTING RESISTANCE OF THE X-LIGHT TUBE IS HIGH


P
S
P

NOTE 141 — FIGURE 18 — ARRANGEMENT OF AN INTERCHANGEABLE SECONDARY INDUCTION COIL WITH ONLY A FEW OF THE SECONDARY SECTIONS IN USE, DIMINISHING THE POTENTIAL


P
S
P

NOTE 143 — FIGURE 1 — NON-RADIABLE X-LIGHT TUBE BOX WITH A CENTRING DIAPHRAGM PLATE HAVING AN ADJUSTABLE RECTANGULAR OPENING, AN ORIENTER, A TESLA SCREEN, AND AN AUTOMATIC SHUTTER


ANGLE AND DISTANCE FINDER
CENTRAL RAY MARKER
TESLA SCREEN USED AS SUPPORT FOR CENTRAL RAY MARKER AND DISTANCE FINDER
ATTACHMENT FOR SHUTTER
NON-RADIABLE TRANSPARENT WINDOW OF LEAD GLASS 4 CENTIMETRES THICK
NON RADIABLE TUBE BOX
SPIRAL SPRING CONNECTION
AUTOMATIC VACUUM REGULATOR
HARD RUBBER

NOTE 143—FIGURE 2

NOTE 143—FIGURE 3

CENTRAL RAY MARKER
ANGLE AND DISTANCE FINDER

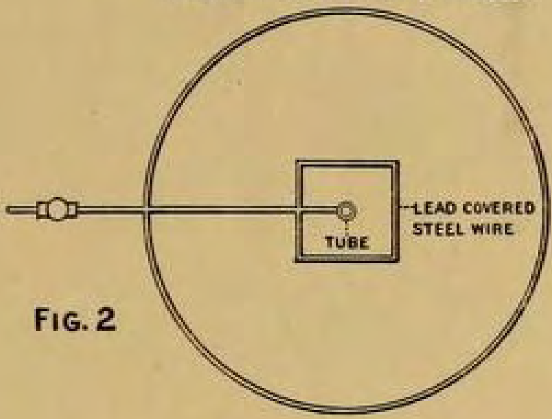
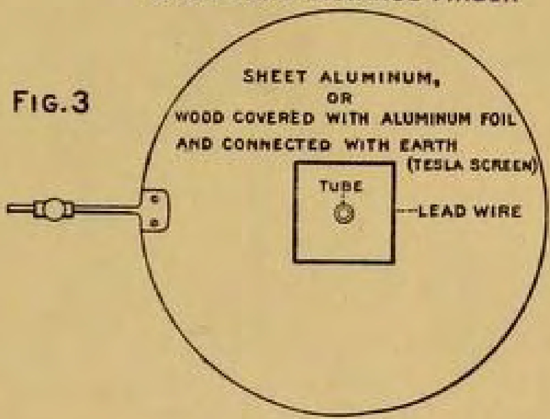


FIG. 2

CENTRAL RAY MARKER
ANGLE AND DISTANCE FINDER

FIG. 3



NOTE 143 — FIGURES 4 AND 5 — ILLUSTRATING THE USE OF AN ORIENTER

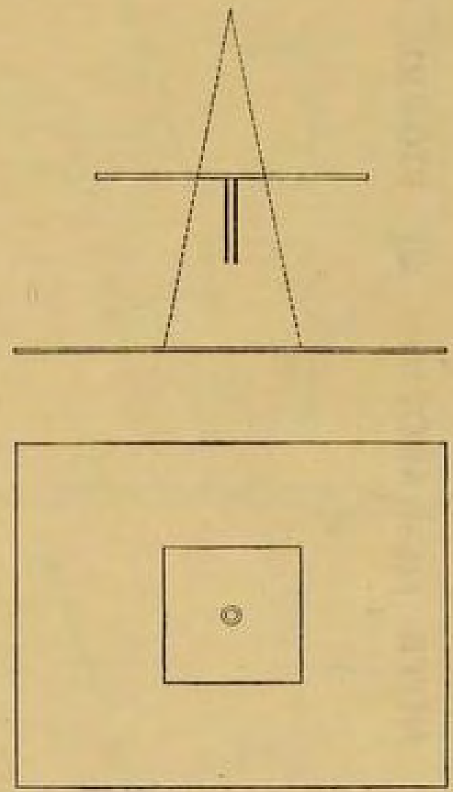


Figure 4

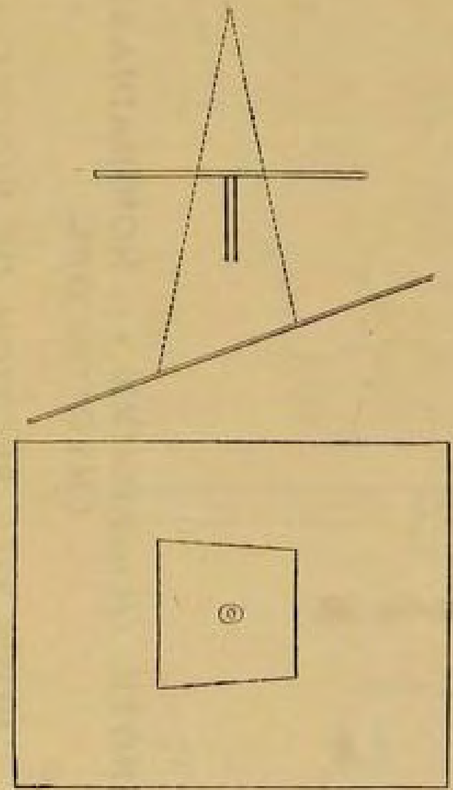


Figure 5

NOTE 145 — FIGURE 1 — NON-RADIABLE CRYPTOSCOPE

NOTE 145 — SECTION OF FIGURE 1

NOTE 145 — FIGURE 2 — NON-RADIABLE CRYPTOSCOPE

NOTE 145 — SECTION OF FIGURE 2

CRYPTOSCOPE

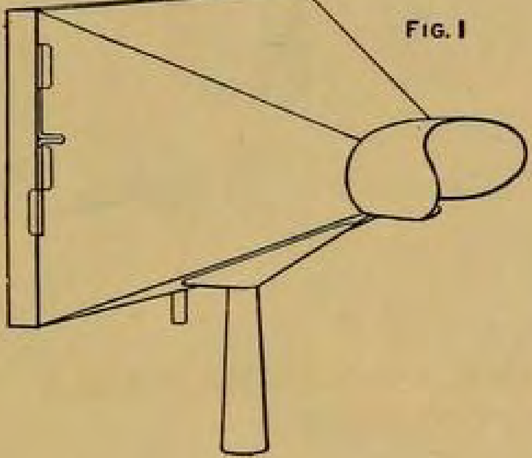
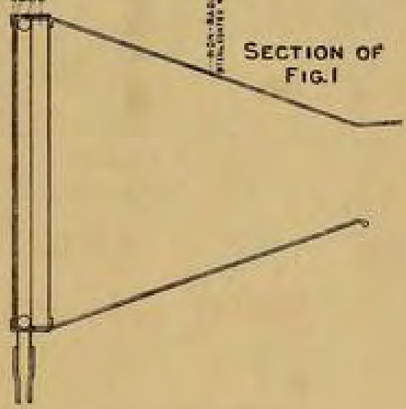


FIG. 1



SECTION OF FIG. 1

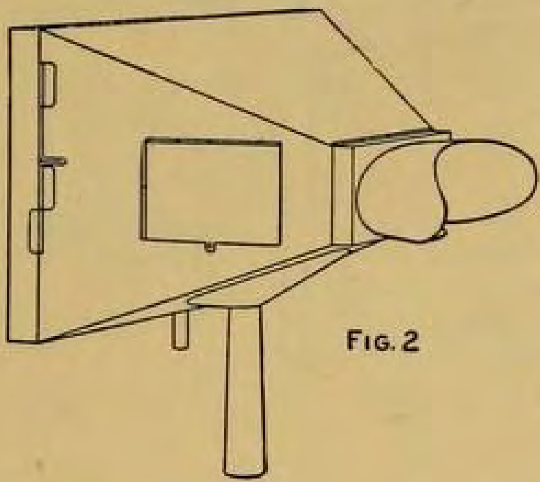
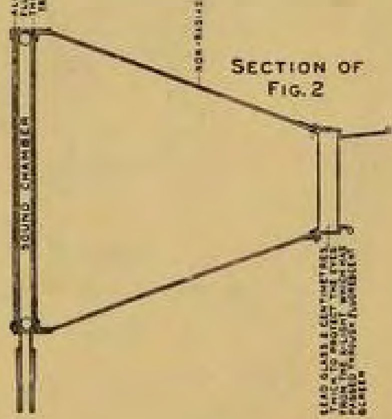


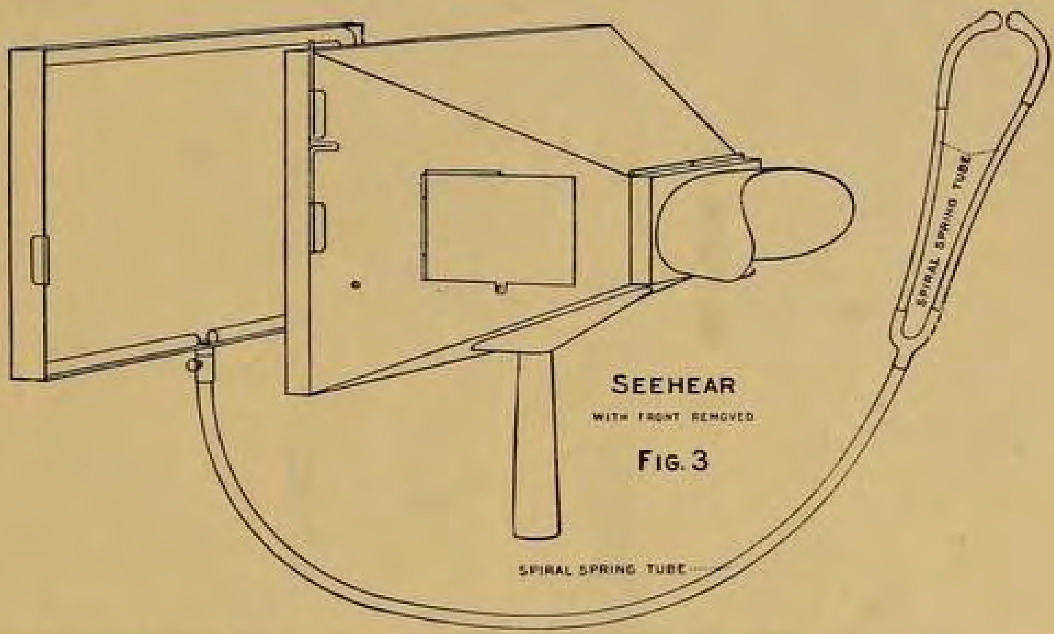
FIG. 2



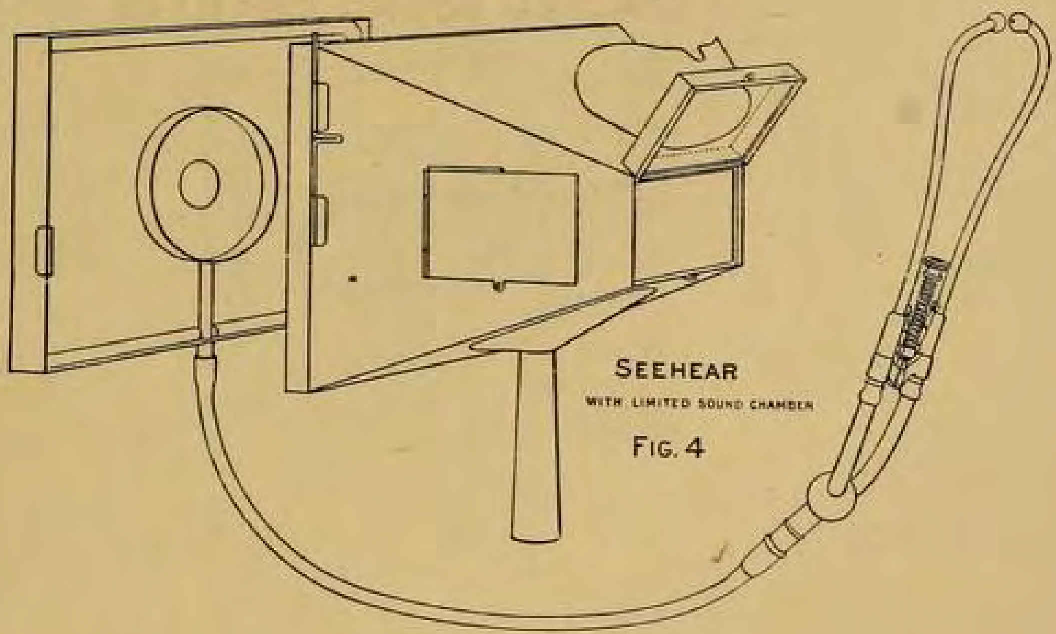
SECTION OF FIG. 2

NOTE 145—FIGURE 3—A SEEHEAR WITH THE FRONT REMOVED

NOTE 145—FIGURE 4—A SEEHEAR WITH A LIMITED SOUND CHAMBER



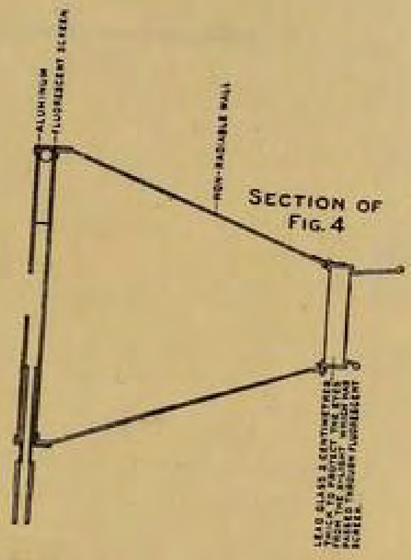
SEEHEAR
WITH FRONT REMOVED
FIG. 3



SEEHEAR
WITH LIMITED SOUND CHAMBER
FIG. 4

NOTE 145 — SECTION OF FIGURE 4 — PLATE 99

NOTE 145 — FIGURE 5 — A CRYPTOSCOPE
USED AS A FINDER



SECTION OF FIG. 4

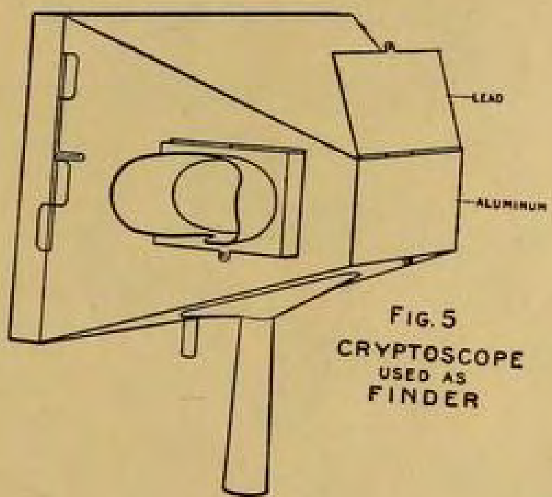


FIG. 5
CRYPTOSCOPE
USED AS
FINDER

NOTE 149 — FIGURE 2 — PLAN OF ADJUSTABLE CENTRING DIAPHRAGM; ORIENTER AND RODS FOR ADJUSTMENT

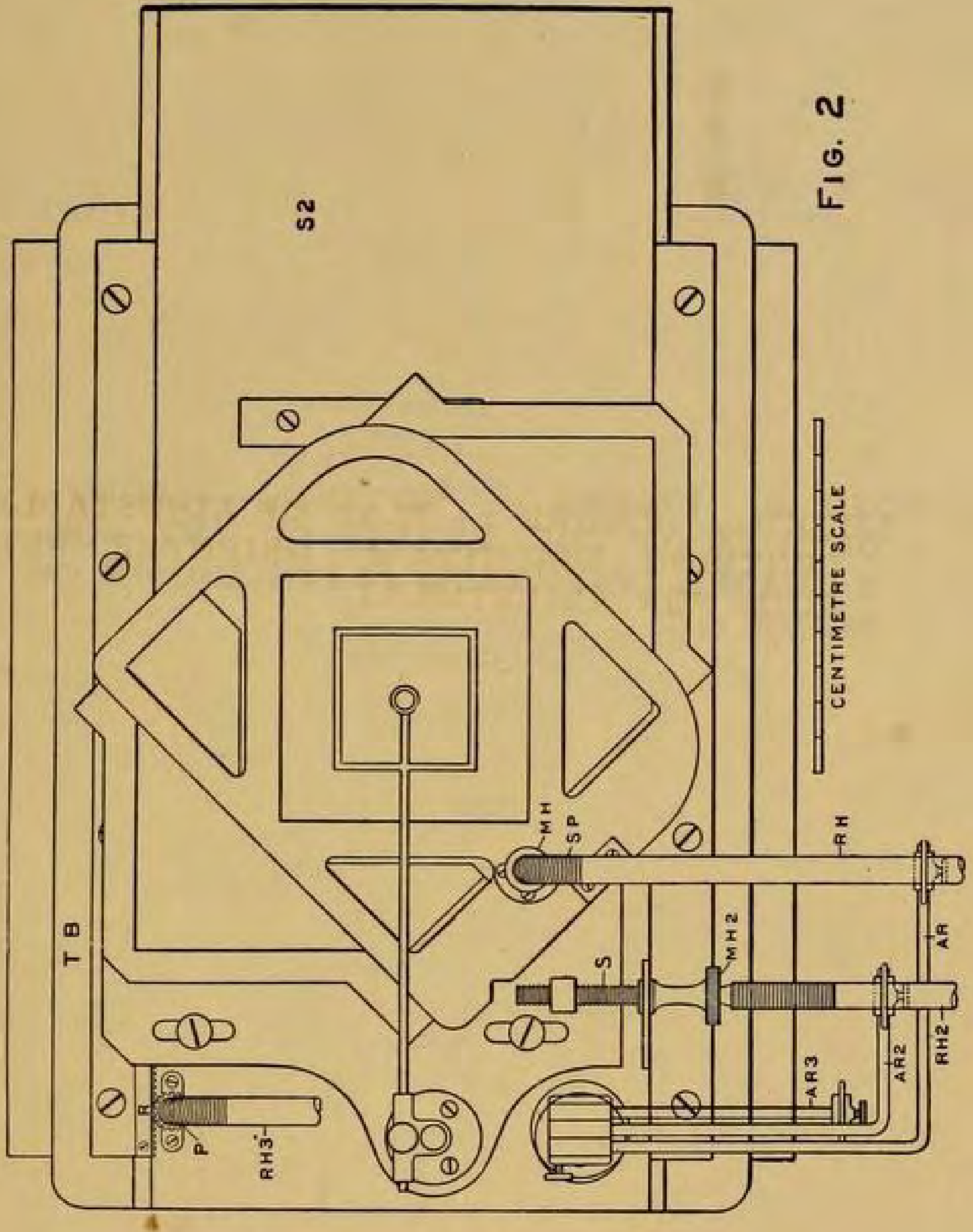


FIG. 2

NOTE 149 — FIGURE 3 NOTE 149 — FIGURE 4

DETAILS OF THE LEAVES OF THE NON-RADIABLE DIAPHRAGM PLATE SHOWN ON PLATE 101

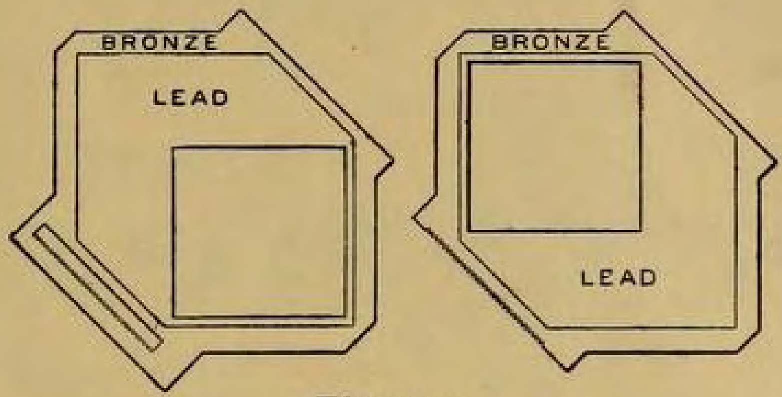


Figure 3

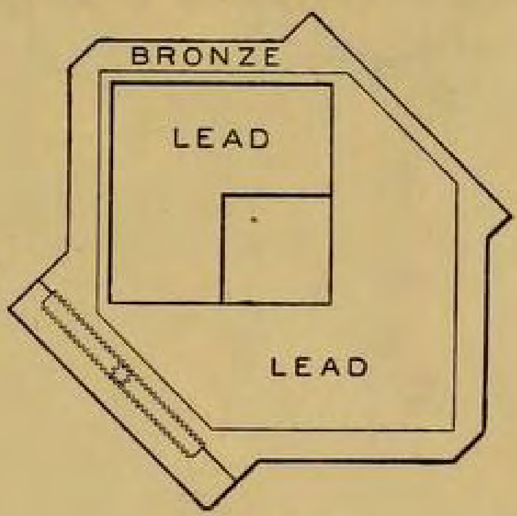
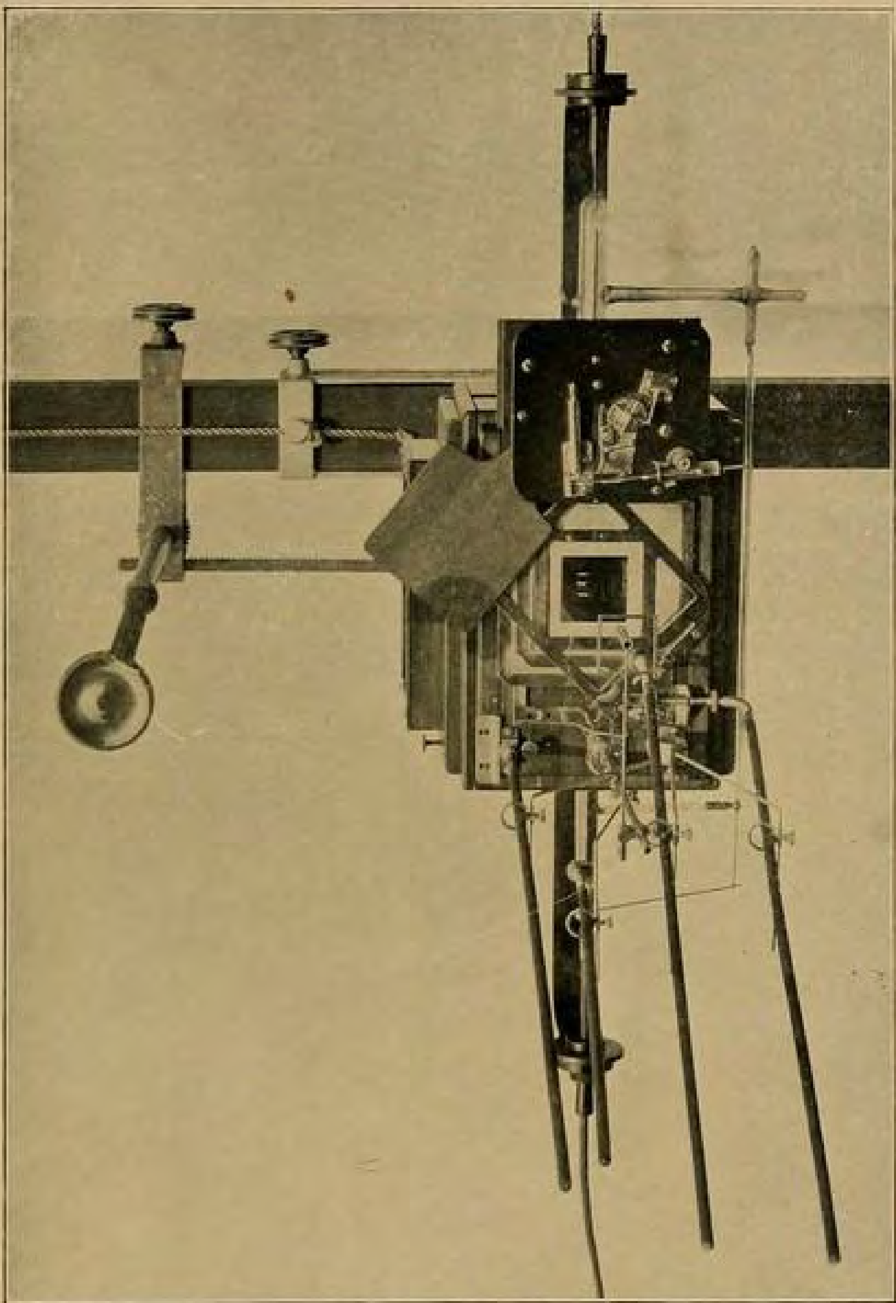
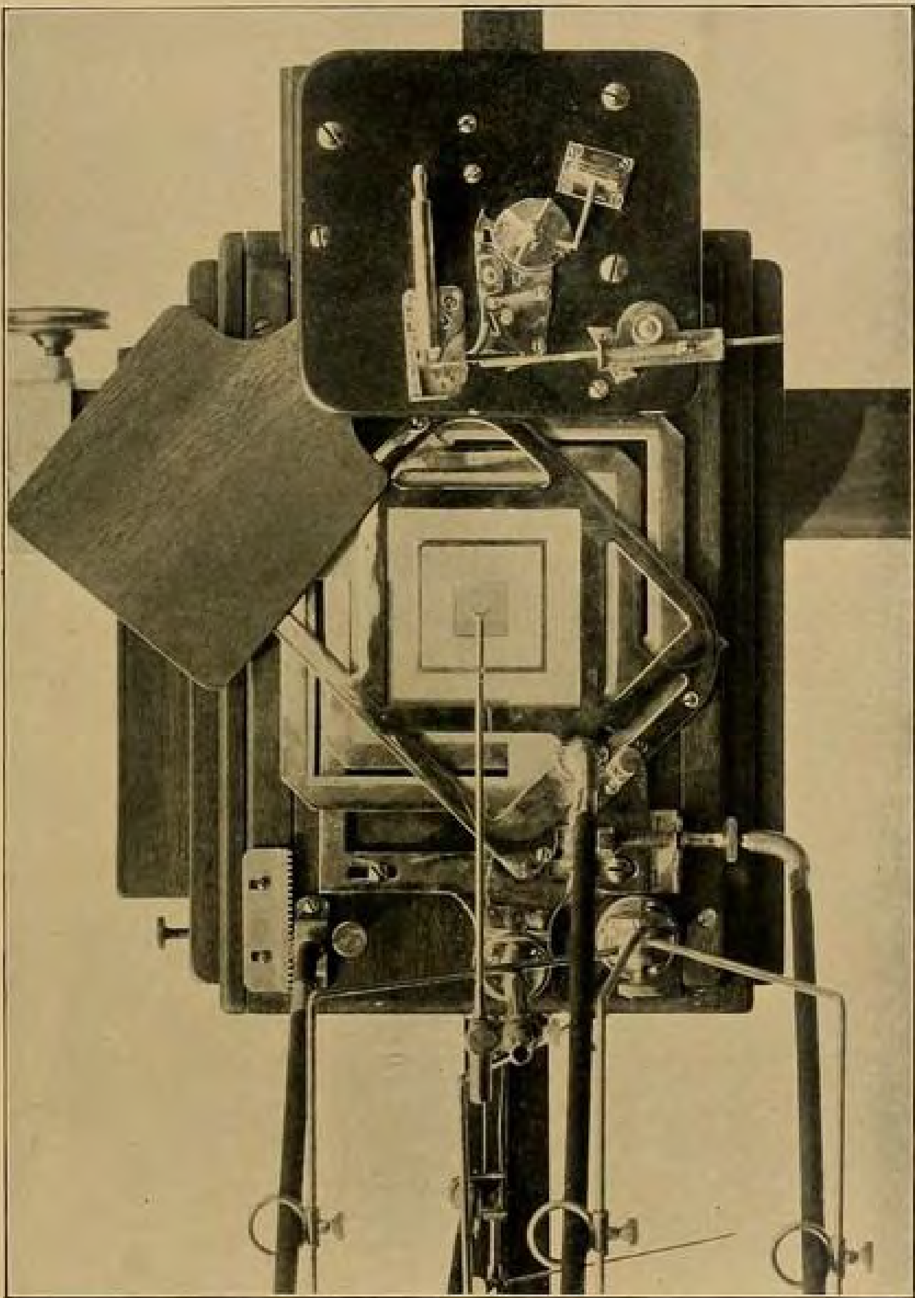


Figure 4

NOTE 149 — FIGURE 5 — A PERSPECTIVE VIEW OF A NON-RADIABLE TUBE BOX


RH 3 . .
RH 4 . .
RH . . .
RH 2 . .

NOTE 149—FIGURE 5A—A TUBE BOX WITH AN ADJUSTABLE, CENTRING DIAPHRAGM; SHUTTER; ORIENTER; VACUUM REGULATOR AND ADJUSTING RODS



RH 3 . .

RH 4 . .

RH . . .

RH 2 . .

NOTE 153 — FIGURE 1 — A CRYPTOSCOPE WITH A PENETRATION GAUGE TURNED BACK AND ACTING AS A COVER TO THE MIRROR

NOTE 153 — FIGURE 2 — A PENETRATION GAUGE TURNED DOWN IN FRONT FOR USE

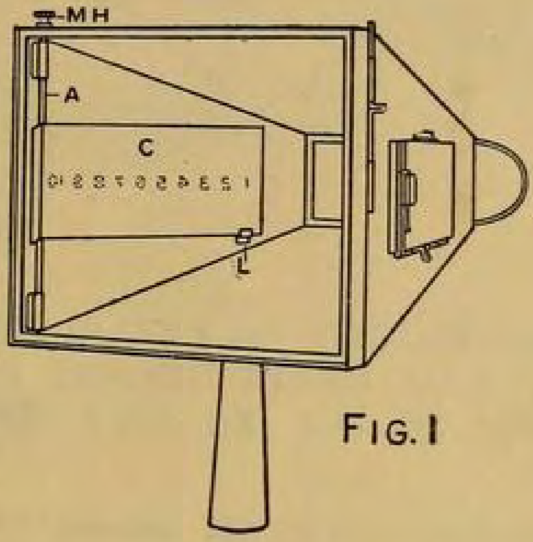


FIG. 1

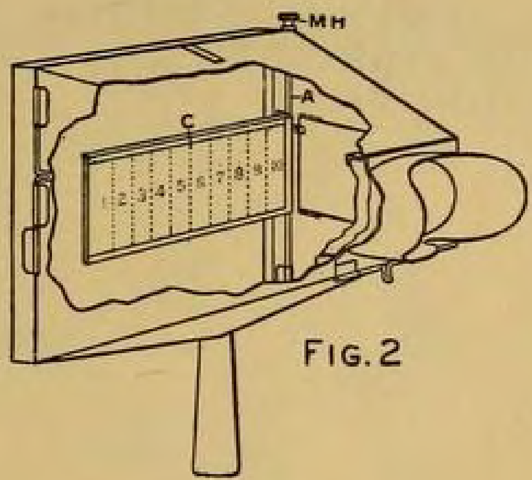
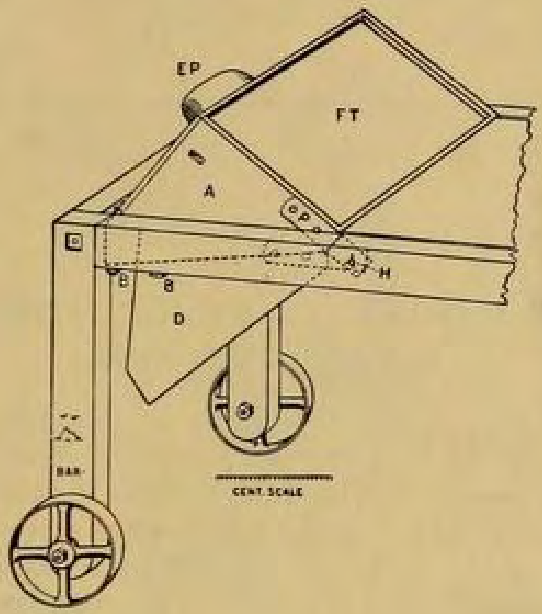


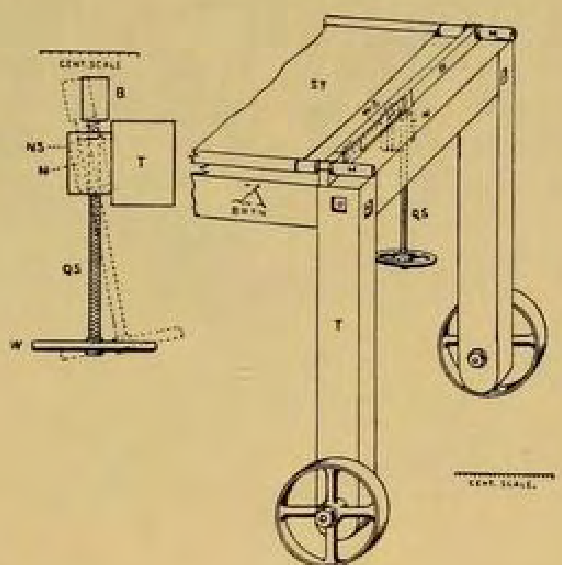
FIG. 2

NOTE 155 — FIGURE 1 — REFLECTING CRYPTOSCOPE AND CRYPTOSCOPIC CAMERA ATTACHED TO AN X-LIGHT EXAMINATION TABLE

A, Reflecting cryptoscopic camera in position. D, Camera turned down out of the way. P, Metal bar fitting over the axis H, enabling the camera to be removed from the examination table. B, Button holding the camera in position, A.

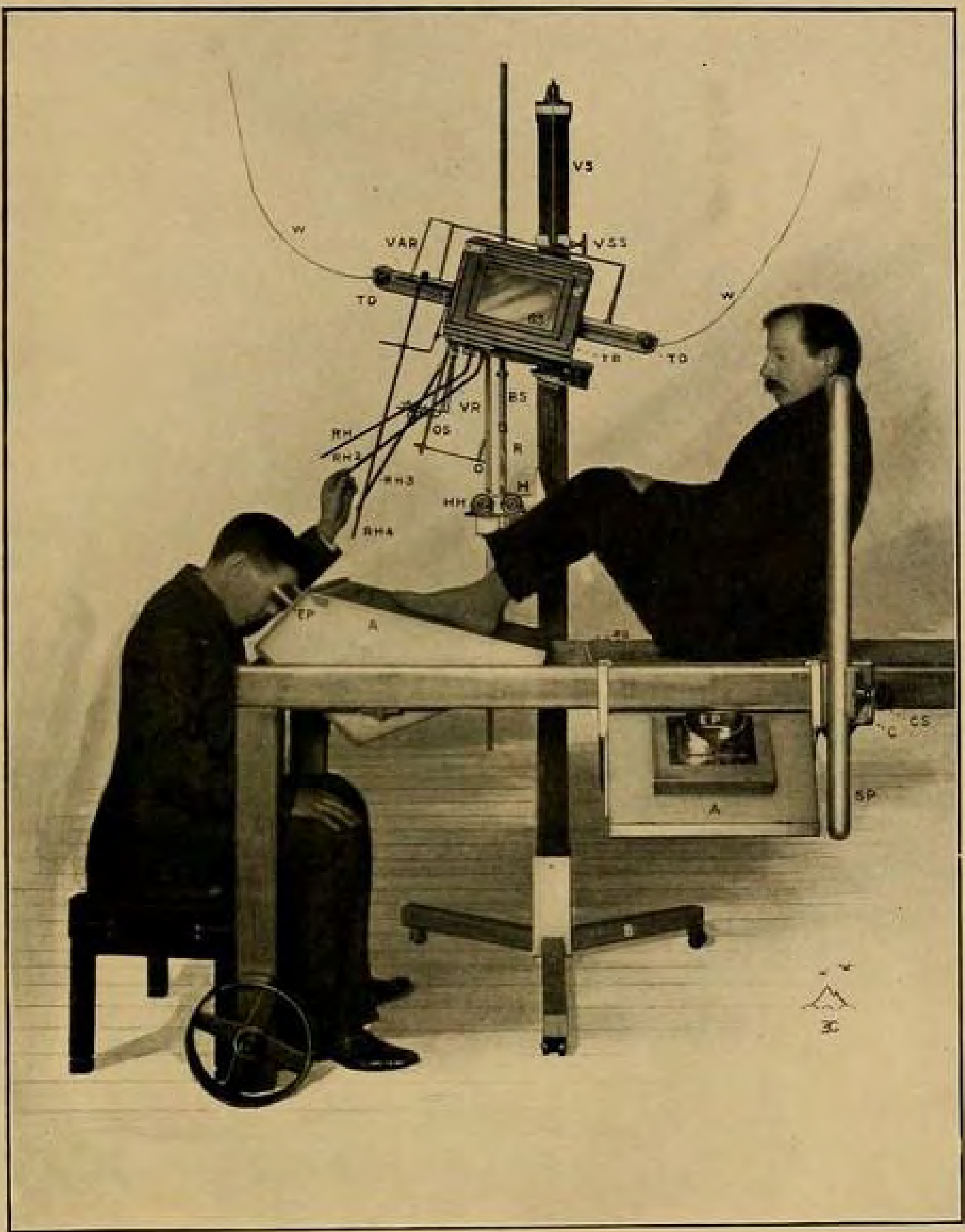
NOTE 155 — FIGURE 5 — LIFTING MECHANISM FOR THE STRETCHER OF AN X-LIGHT EXAMINATION TABLE


EP
FT
A
P
B
B
H
D
BAR
CENT. SCALE


CENT. SCALE
B
NS
T
QS
W
ST
QS
T
CENT. SCALE.

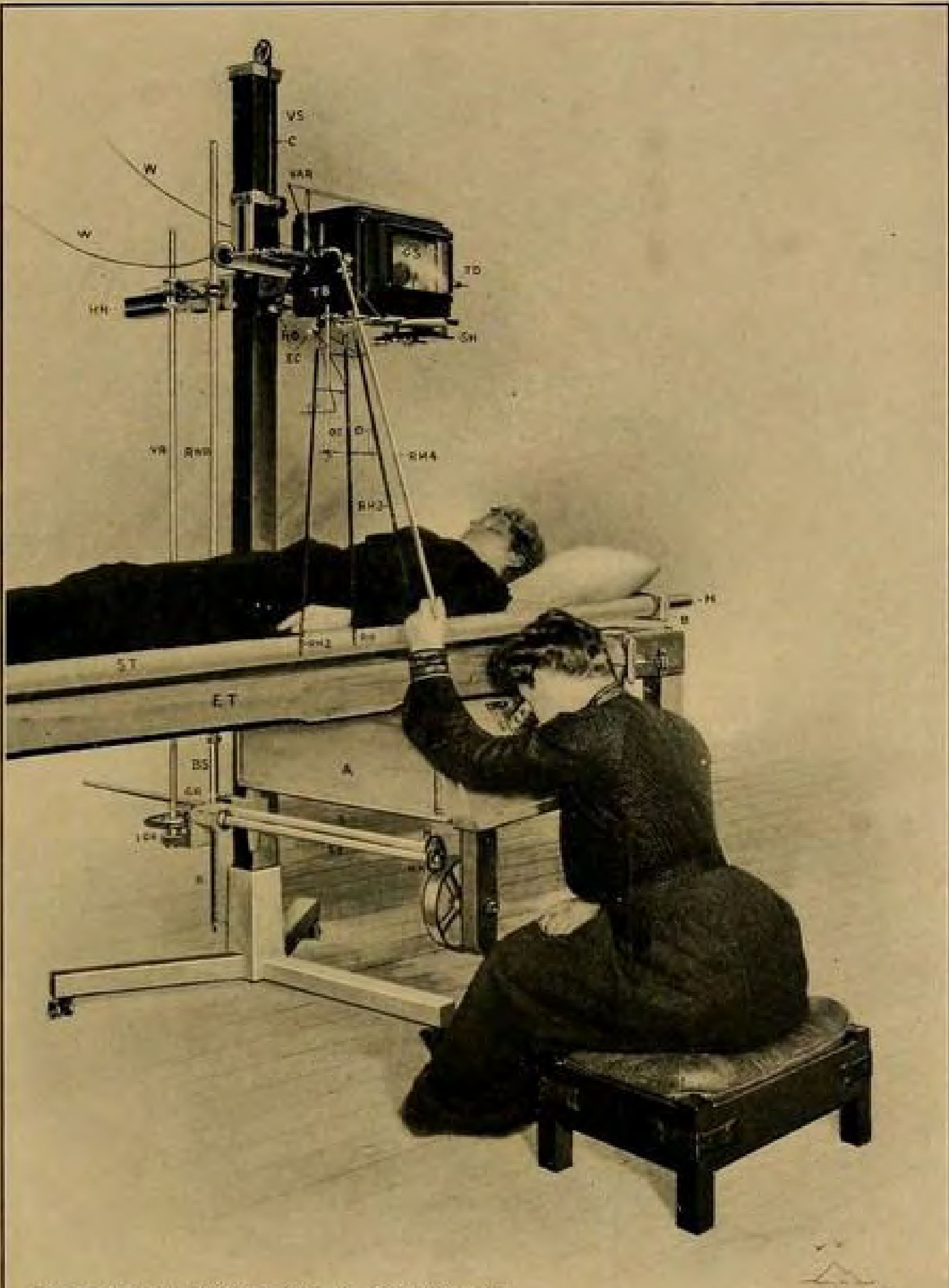
NOTE 155 — FIGURE 3 — REFLECTING CRYPTOSCOPIC CAMERA

Reflecting cryptoscopic camera in use for photographing the feet for signalment by X-light. The observer has within reach, while looking in the camera, six handles, two of which, H and HH, regulate the distance of the source of X-light and allow it to be moved in a horizontal plane. Taken in connection with rolling movements of the examination table, they enable the source of X-light to be quickly brought into proper relations with fluorescent screen. Handle RH 4 controls the quality of the X-light. Handles RH and RH 3 enable the opening of the diaphragm and the orienter to be centred with the source of X-light. Handle RH 2 regulates the size of the area of the patient illuminated. This illuminated area must be as small as possible to avoid injuring the definition of the image on the screen and on the photographic plate. For further explanation of the letters refer to descriptions under the illustrations 1 and 4, Plates 109 and 112, Note 156, and to the text of Notes 148, 149, 150, 151, 155.


VS
VSS
VAR
W
W
TD
TD
TR
BS
VR
OS
RH
RH2
RH3
RH4
R
O
HH
H
TP
A
CS
C
SP
A
B

NOTE 155 — FIGURE 4 — EXAMINATION OF A PATIENT WITH A REFLECTING CRYPTOSCOPE AND CAMERA

The figure shows a reflecting cryptoscopic camera in use for photographing the spine, the patient being in a horizontal position on the stretcher, ST, of the examination table, ET. The observer looks into the eye-piece, EP, of the camera, A, and sees on the mirror an image of the spine made by the X-light on the fluorescent screen at the top of the camera directly under the patient. It will be observed that the stretcher is slightly raised at the head to bring the axis of the spine nearly parallel with the screen and consequently with the photographic plate. By means of the handles, HH, H, RH, RH 2, RH 3, the direction of the source of X-light and the size of the illuminated area of the patient can be controlled by the observer while making the examination. The quality of the X-light is controlled by the handle RH 4. For further explanation of the letters refer to the description under Plate 109, Figure 1, Note 156, and to the text of that note.



REFLECTING CRYPTOSCOPIC X-LIGHT CAMERA

NOTE 155 — FIGURE 2 — A REFLECTING CRYPTOSCOPIC CAMERA

NOTE 155 — FIGURE 2 A — A REFLECTING CRYPTOSCOPIC CAMERA FOR PHOTOGRAPHING THE FEET

NOTE 155 — FIGURE 6 — LIFTING MECHANISM FOR THE STRETCHER OF THE X-LIGHT EXAMINATION TABLE

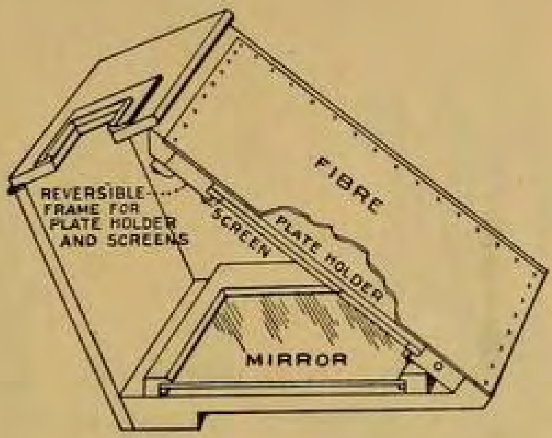


Figure 2

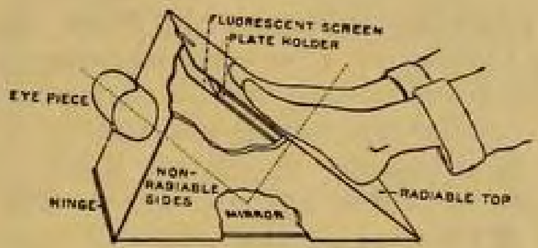


Figure 2 A

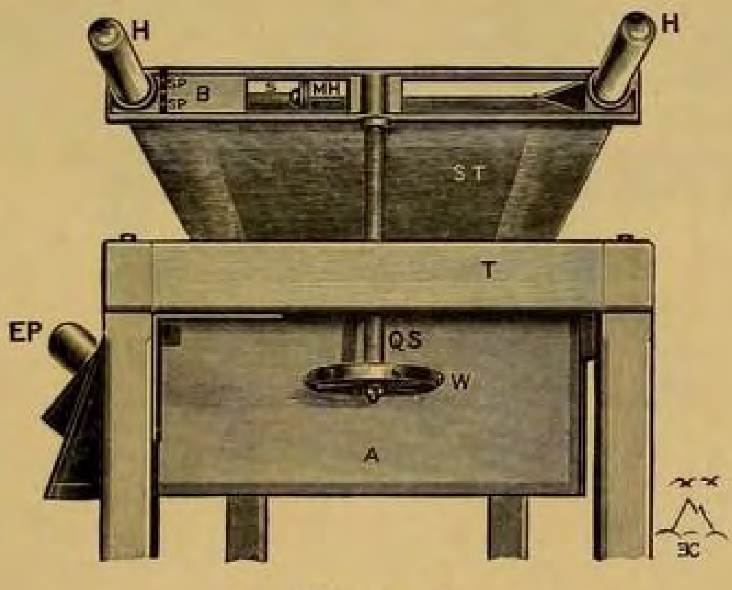
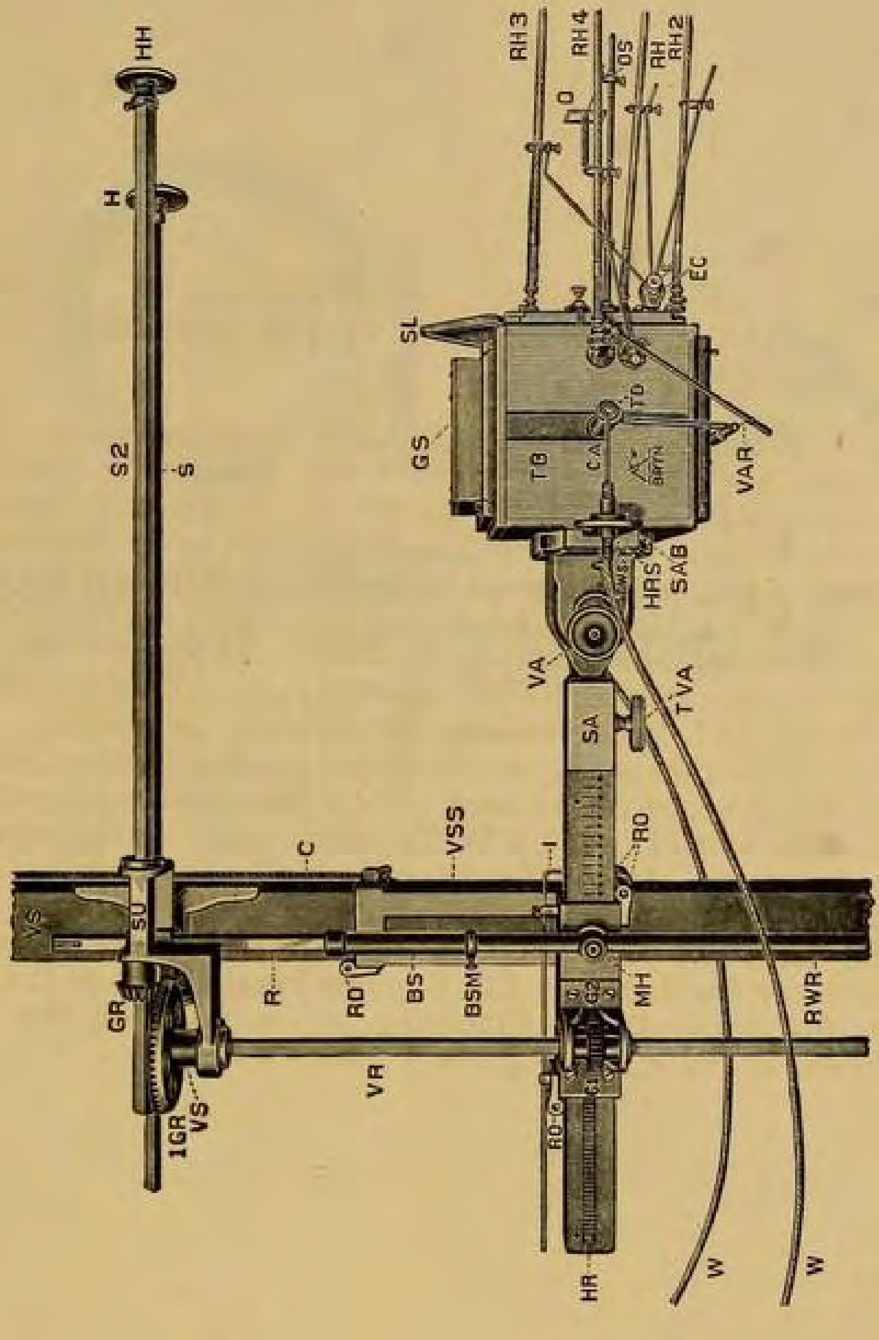


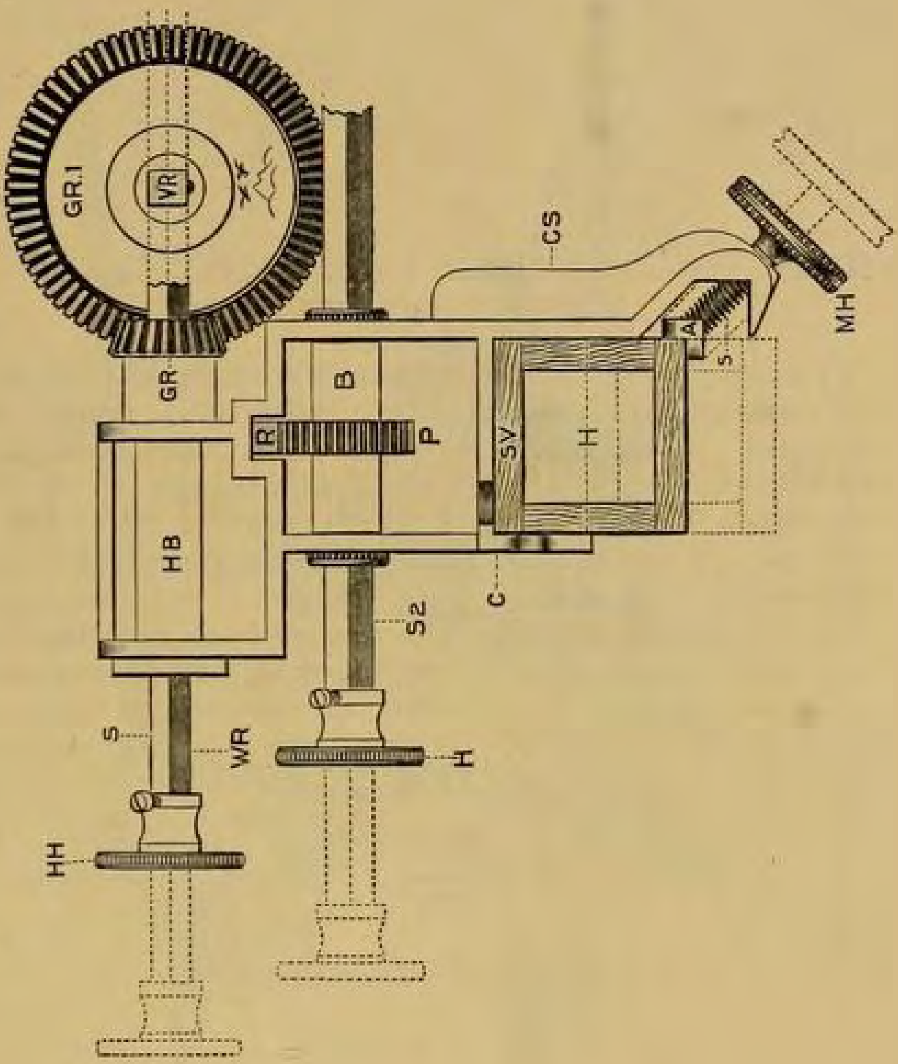
Figure 6

NOTE 156 — FIGURE 1 — DETAILS OF A NON-RADIABLE X-LIGHT TUBE-HOLDER AND ITS SUPPORT

W, Wires to generator. C, Cord to counterpoise. RH, Handle regulating the size of the opening in the diaphragm plate -refer to the figures in Note 149 for details-. RH 2, Handle raising or lowering opening in diaphragm plate. RH 3, Handle moving the diaphragm plate horizontally. RH 4, Handle regulating the quality of the X-light by operating the vacuum regulator VAR. O, Orienter -for details refer to Notes 143 and 150-. OS, Support for orienter. SL, Slide closing the opening in shutter. GS, Slide with transparent non-radiable window through which the X-light tube can be seen. TVA, Screw-clamping movement in vertical arc. TD, Terminal plate of the wire W to generator. HRS, Hard rubber sleeve for terminal wire W. SAB, Sliding wooden arm supporting terminal wire and terminal disk -refer to Plate 115, Figures 1 and 2, Note 157, for details-. EC, Support for the arms of the regulating handles. E, Clamping screw made on the plan shown in Plate 113, Figures 5 and 6.

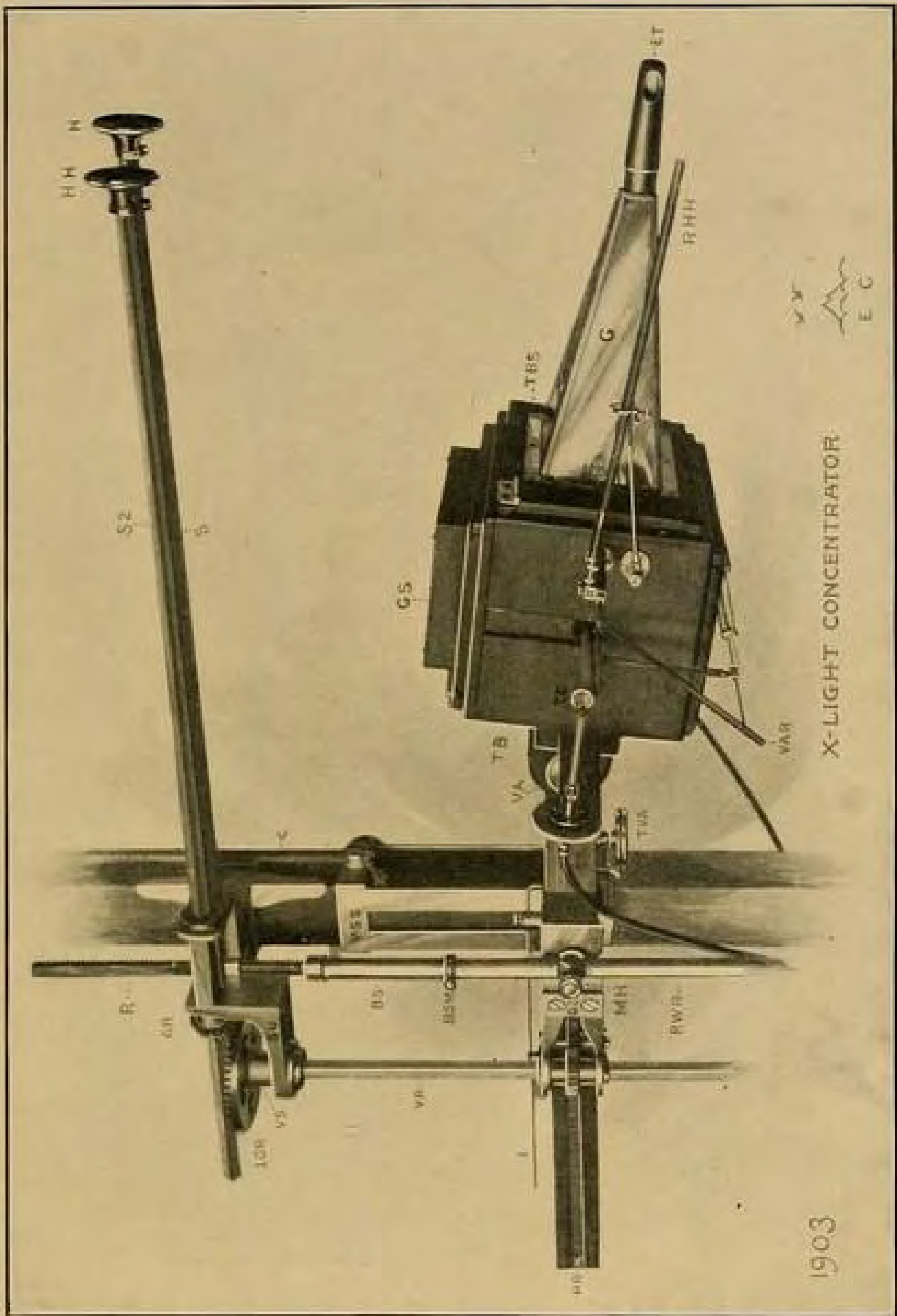

HH
H
S2
S
VS
SU
GR
1GR
VS
C
VSS
R
RD
BS
BSM
VR
I
RD
MH
RWR
RD
HR
W
W
SA
TVA
VA
HRS
SAB
VAR
GS
TB
CA
TD
SL
EC
RH3
RH4
D
DS
RH
RH2

NOTE 156 — FIGURE 2 — DETAILS OF SUPPORT -SU- SHOWN IN FIGURE 1, PLATE 109


GR.1
VR
GR
B
R
P
HB
SV
H
CS
MH
A
S
C
S2
S
WR
H
HH

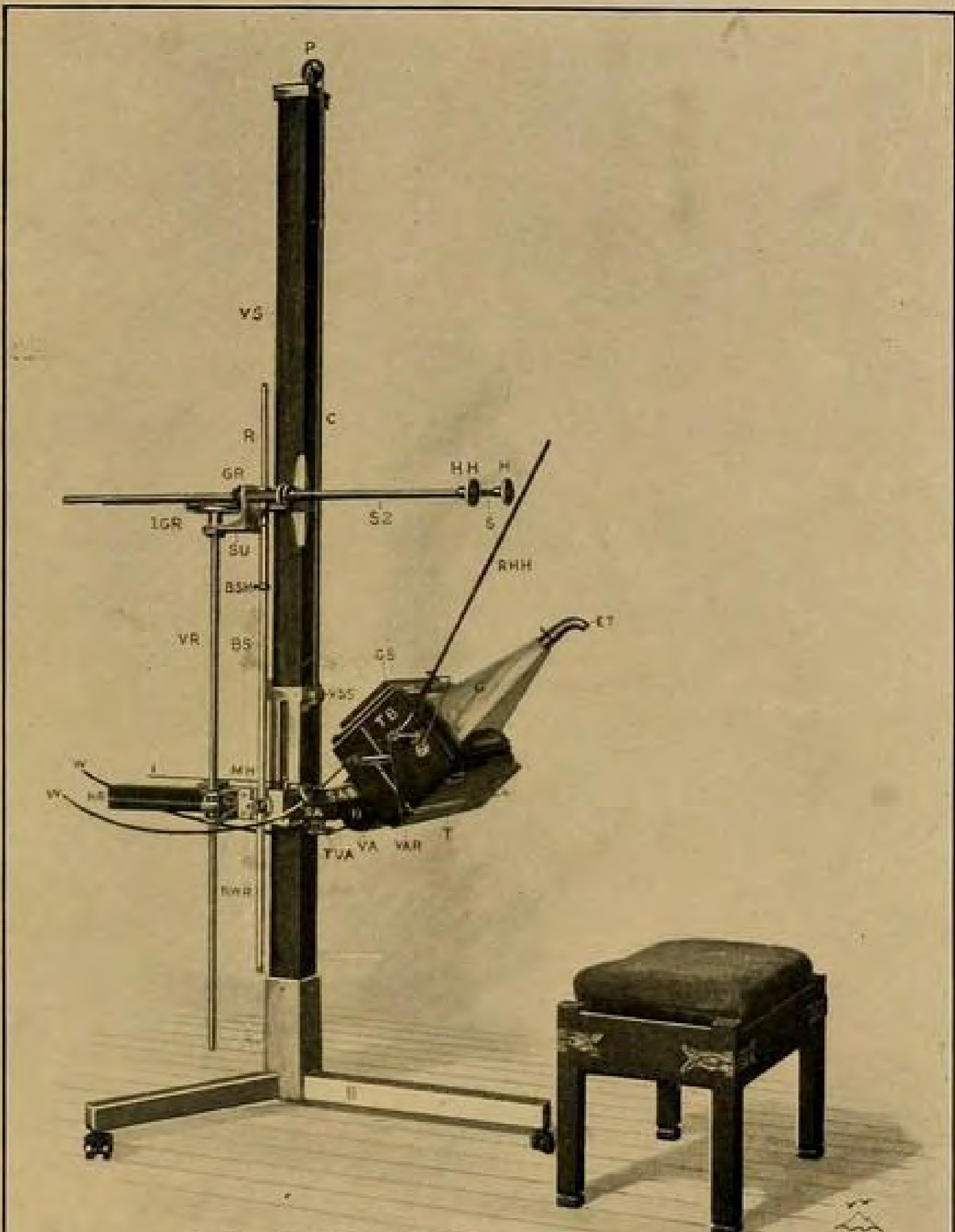
NOTE 156 — FIGURE 3 — X-LIGHT TUBE BOX WITH CONCENTRATOR

To the non-radiable tube box TB is attached a pyramid of non-radiable material lined with zinc which reflects X-light. To the end a lead tube -lined with zinc-, with an aperture ET in the side, is attached, through which the concentrated X-light escapes to the part of the body to be treated. A number of ends of different sizes and shapes are required. The quality of the X-light is regulated by turning the handle RHH. The movements described in the text allow the end ET to be brought into proper relations with the patient. For further explanation of the lettering refer to the explanation under Plate 109, Figure 1, and to the text.


X-LIGHT CONCENTRATOR
1903

NOTE 156—FIGURE 4—A NON-RADIABLE X-LIGHT TUBE BOX WITH AN X-LIGHT CONCENTRATOR ARRANGED FOR TREATING DISEASES OF THE MOUTH

The figure shows an X-light concentrator in position for treating a disease of the mouth. The end ET of non-radiable material is placed in the mouth against the diseased area. By means of the handles H and HH and the movements in vertical arc described in the text, the opening in the end ET can be brought into correct relations with the patient, who sits on the stool. For a further description of the lettering refer to the text and to the description under Plate 109, Figure 1.



1903 X-LIGHT CONCENTRATOR & X-LIGHT REGULATOR.

NOTE 156 — FIGURES 5 AND 6 — DETAILS OF THE PIVOT MECHANISM OF AN X-LIGHT TUBE-HOLDER

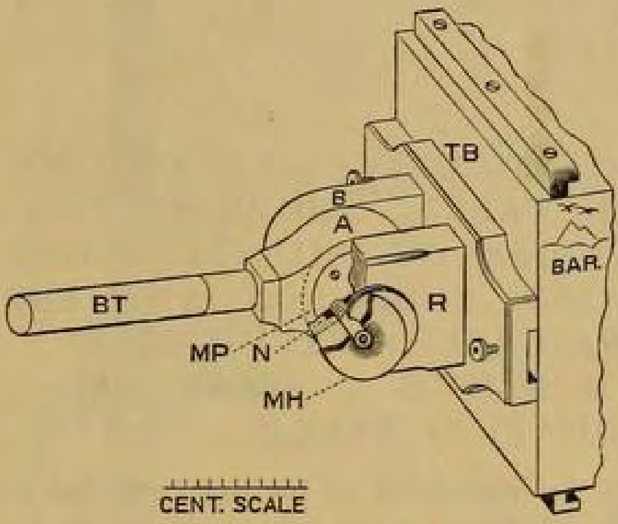


Figure 5

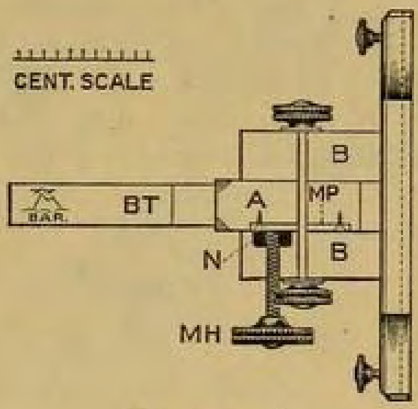
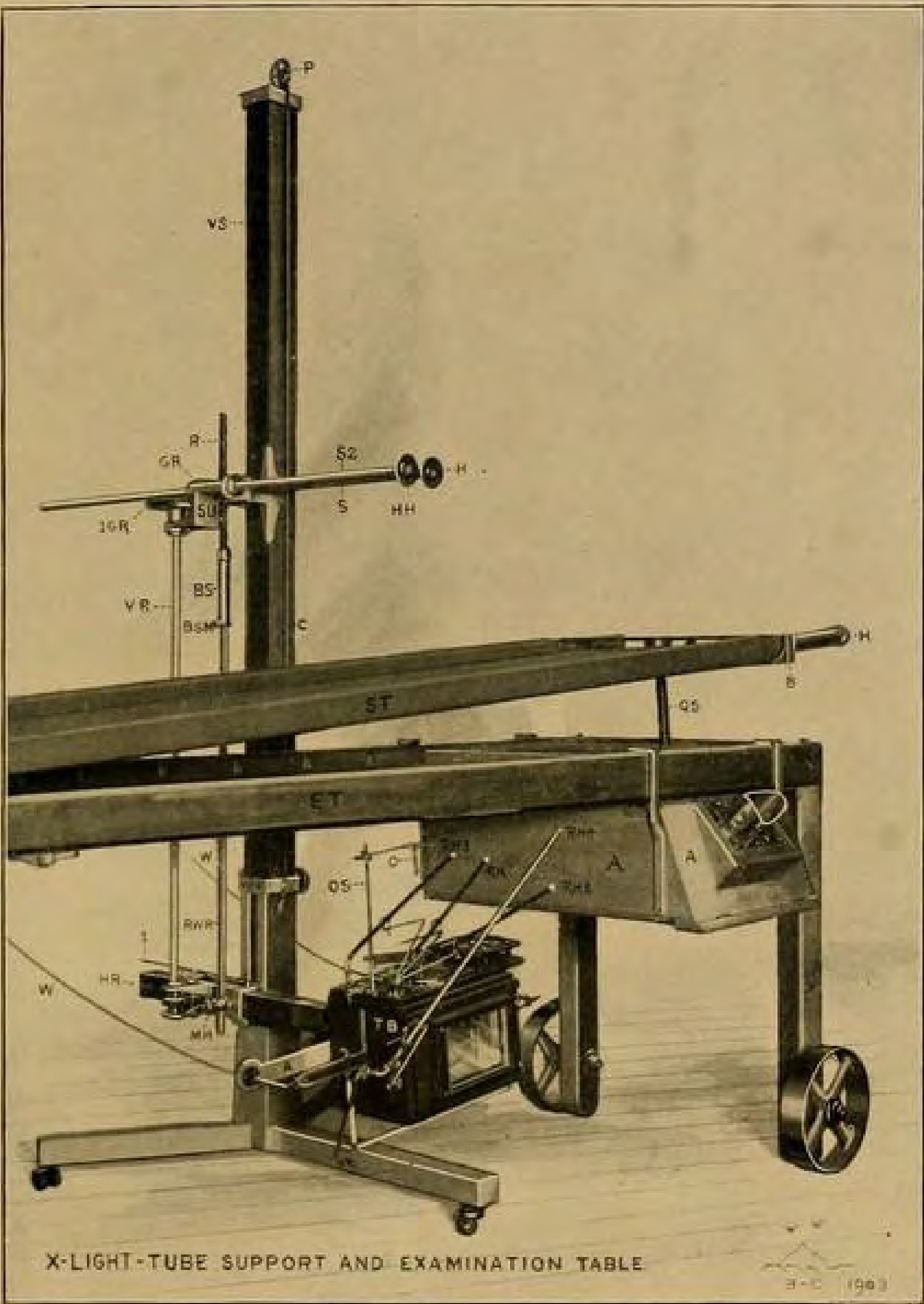


Figure 6

NOTE 156 — FIGURE 7 — AN X-LIGHT EXAMINATION TABLE, SHOWING THE LIFTING MECHANISM OF THE STRETCHER: A NON-RADIABLE TUBE BOX AND SUPPORT: A NON-RADIABLE CRYPTOSCOPIC CAMERA WHICH SLIDES ON THE RAILS OF THE EXAMINATION TABLE

To show the necessity of having the tube box turn in a vertical plane about an axis parallel with the transverse axis of the X-light tube. With the stretcher ST tipped as it must be in some cases -as shown in Note 139, for example- the central ray of X-light escaping from the tube box and used to take the photograph could not strike the plate normal to its surface without this movement. The tube box appears to be tipped more than the stretcher, but this is an effect of perspective due to the short focus of the lens which was used in making the photograph. For further explanation of the letters refer to the text and to Plate 109, Figure 1.



X-LIGHT-TUBE SUPPORT AND EXAMINATION TABLE

NOTE 157 — FIGURES 1 AND 2 — DETAILS OF A METHOD OF CONNECTING AN X-LIGHT TUBE WITH THE WIRES FROM THE ELECTRICAL GENERATOR

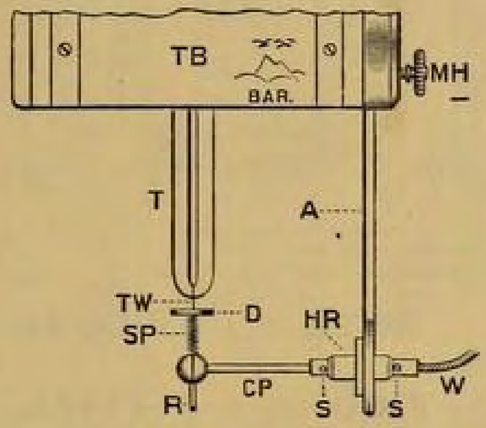


Figure 1

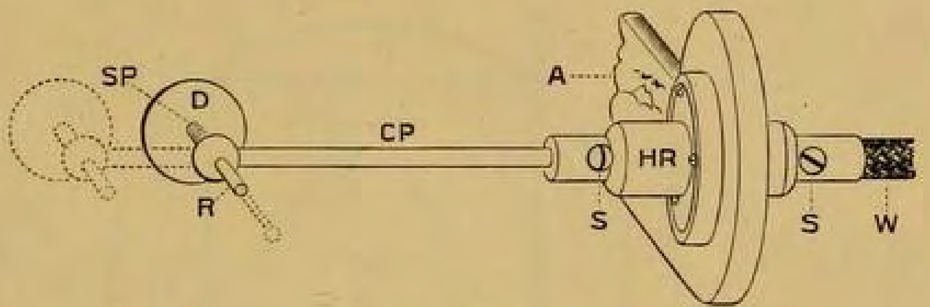
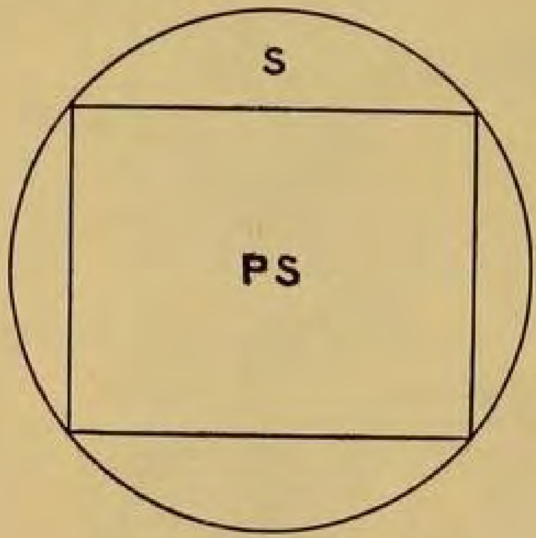


Figure 2

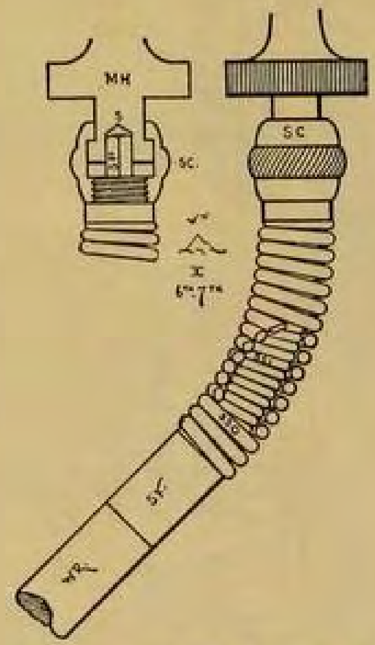
NOTE 149 — FIGURE 1

NOTE 156 — FIGURE 8 — SPIRAL SPRING CONNECTIONS OF THE ADJUSTING RODS OF THE NON-RADIABLE TUBE BOX SHOWN IN PLATE 109

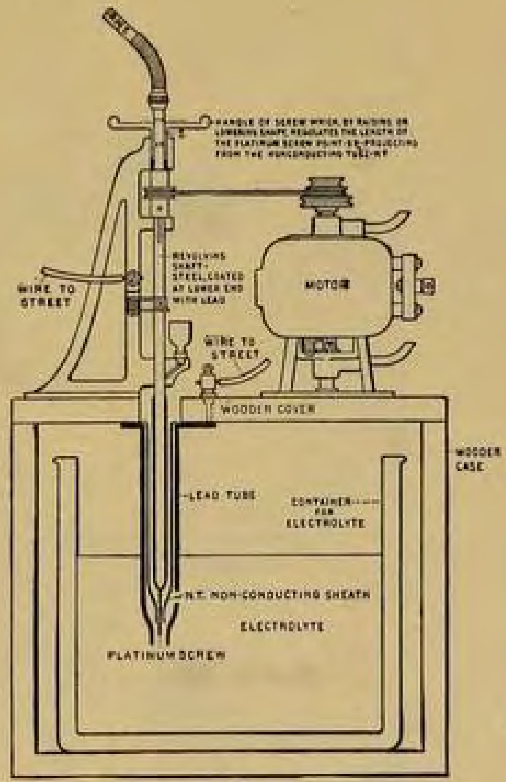
NOTE 161 — FIGURE 1 — A FORM OF ELECTROLYTIC BREAK



Note 149 — Figure 1

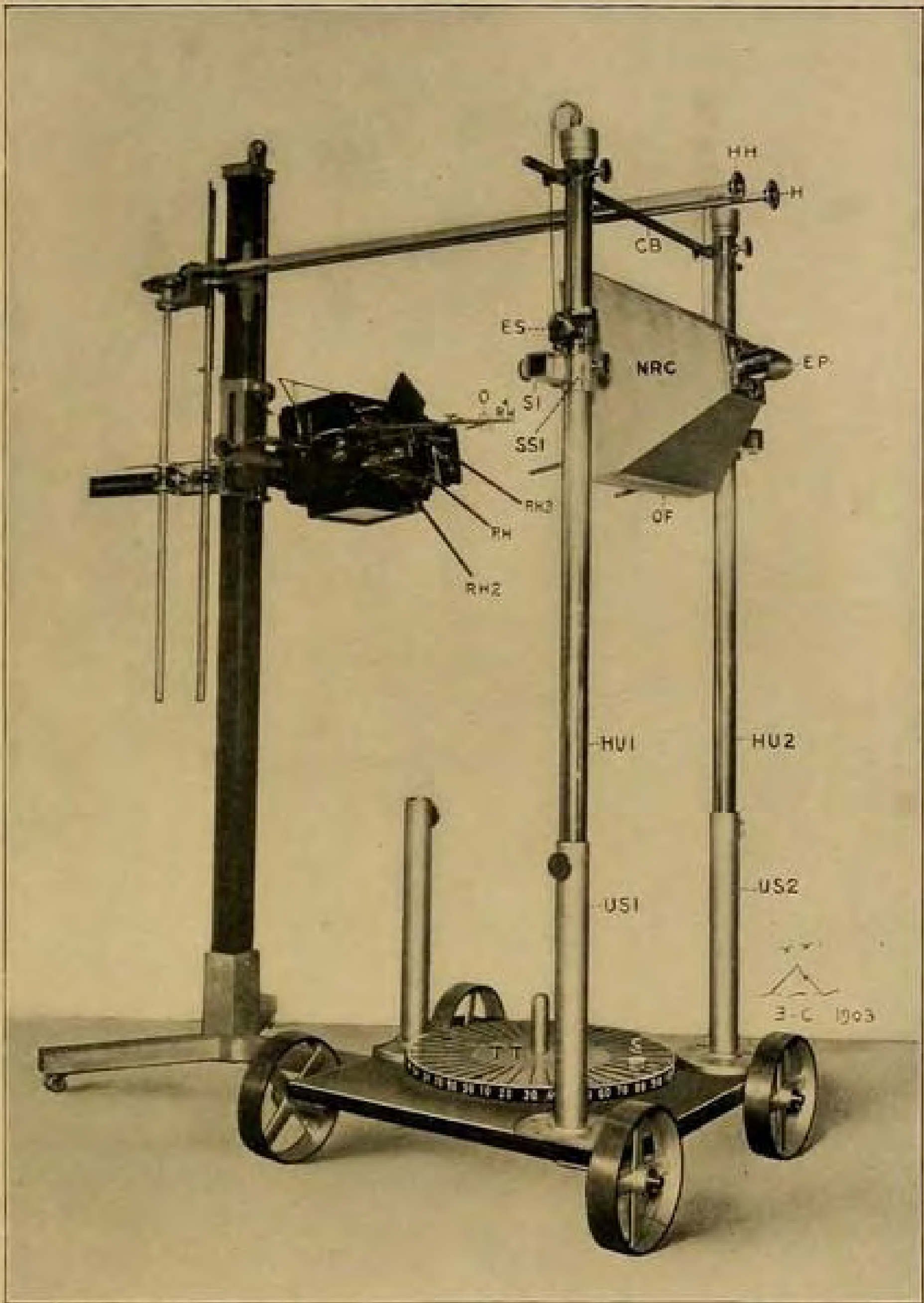


Note 156 — Figure 8



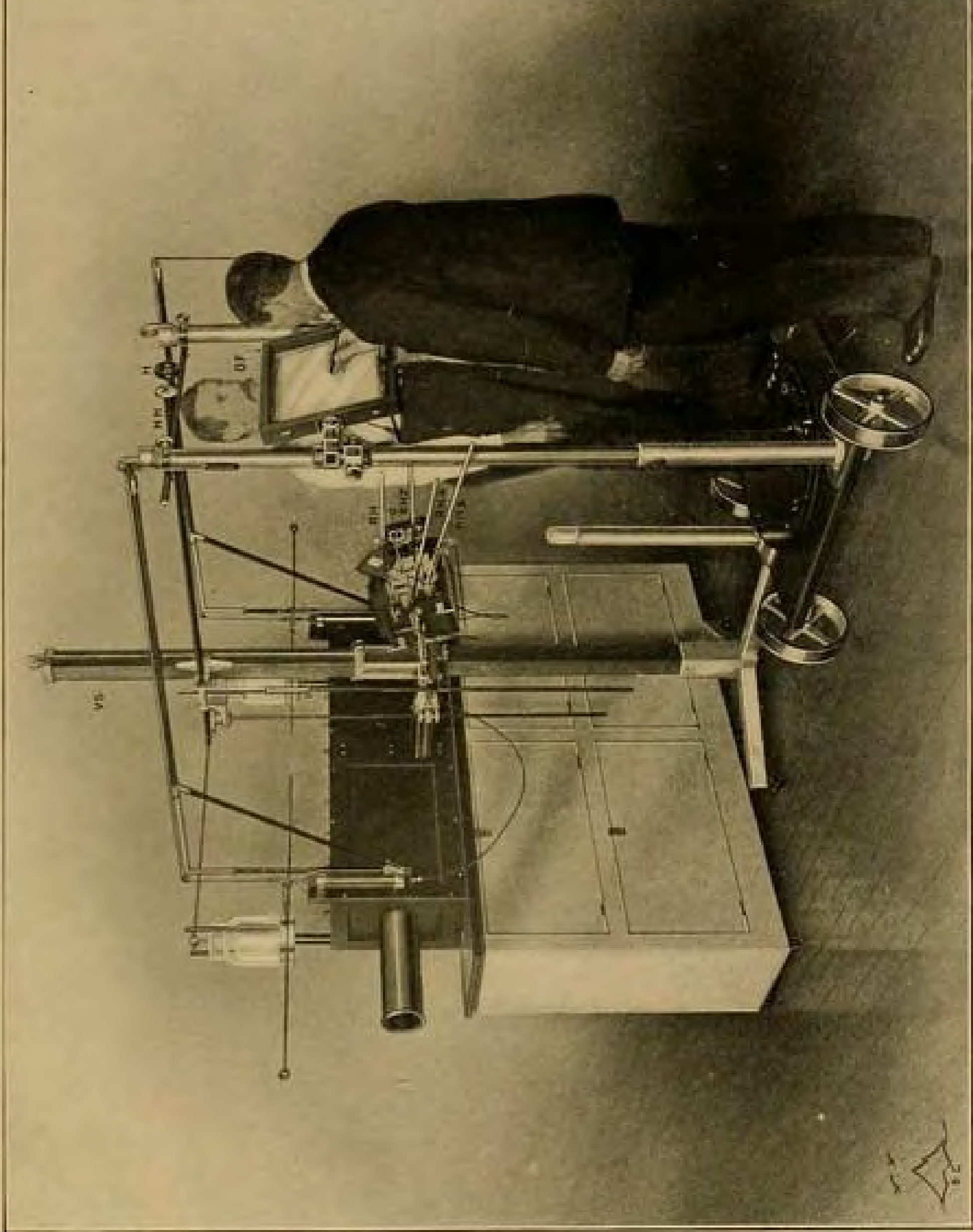
Note 161 — Figure 1

NOTE 162—FIGURE 1—AN X-LIGHT EXAMINATION WAGON, TUBE BOX, AND SUPPORT FOR EXAMINING A PATIENT IN A STANDING POSITION


HH
H
CB
ES
NRC
EP
S1
SS1
RH2
QF
HU1
HU2
US1
US2

NOTE 162—FIGURE 1 A—EXAMINING THE CHEST WITH THE PATIENT ON THE X-LIGHT WAGON, SHOWING THE METHOD OF USING THE TRACING FRAME

The various handles are numbered to correspond with those in other figures, which should be consulted.



NOTE 162 — FIGURE 3 — DETAILS OF A TRACING FRAME FOR THE X-LIGHT WAGON SHOWN ON PLATE 117

NOTE 162 — FIGURE 4 — DETAILS OF THE CRYPTOSCOPE OF THE X-LIGHT WAGON SHOWN ON PLATE 117

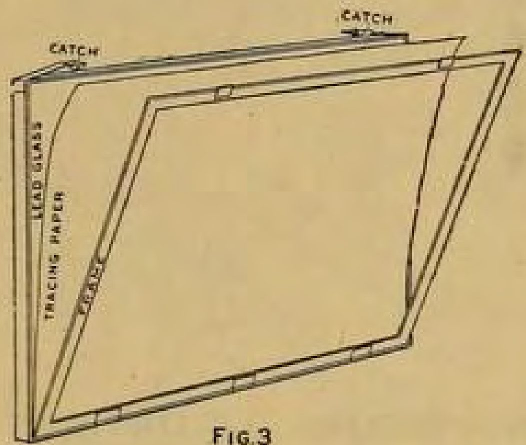

CATCH
CATCH
LEAD GLASS
TRACING PAPER
FRAME

FIG. 3

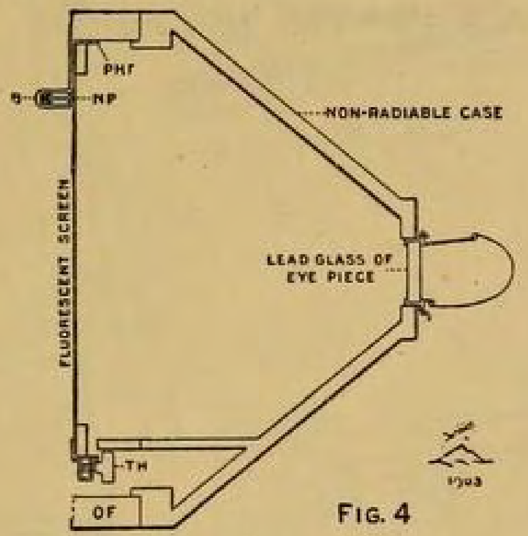

PHF
NP
NON-RADIABLE CASE
FLUORESCENT SCREEN
LEAD GLASS OF
EYE PIECE
TH
OF
1903

FIG. 4

NOTE 162—FIGURE 2—DETAILS OF THE TRACING FRAME

NOTE 162—FIGURE 5—A TRACING FRAME ATTACHED TO THE EXAMINATION TABLE SHOWN ON PLATES 106, 107, 114

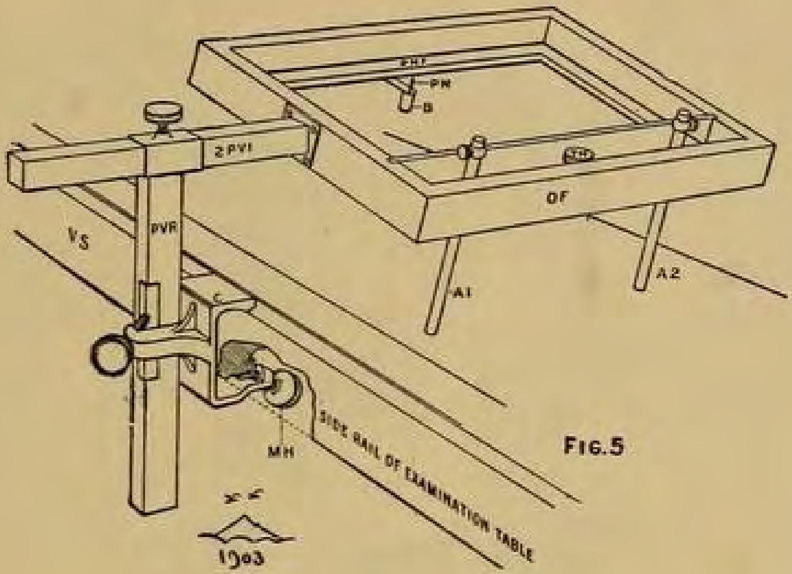

PHF
PN
B
2PVI
PVR
VS
OF
A1
A2
MH
SIDE RAIL OF EXAMINATION TABLE
1903

FIG. 5

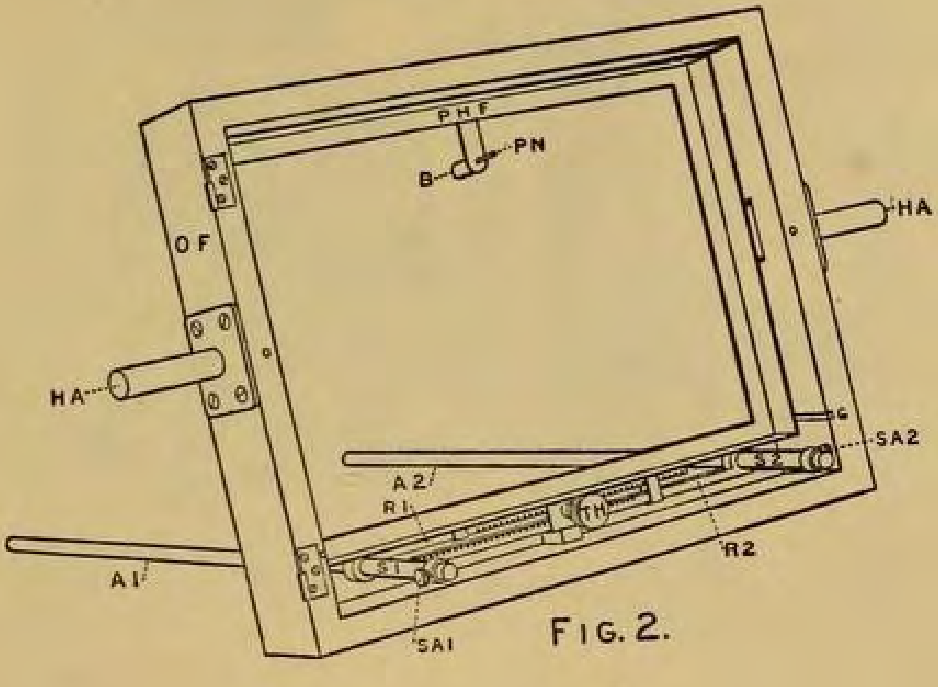
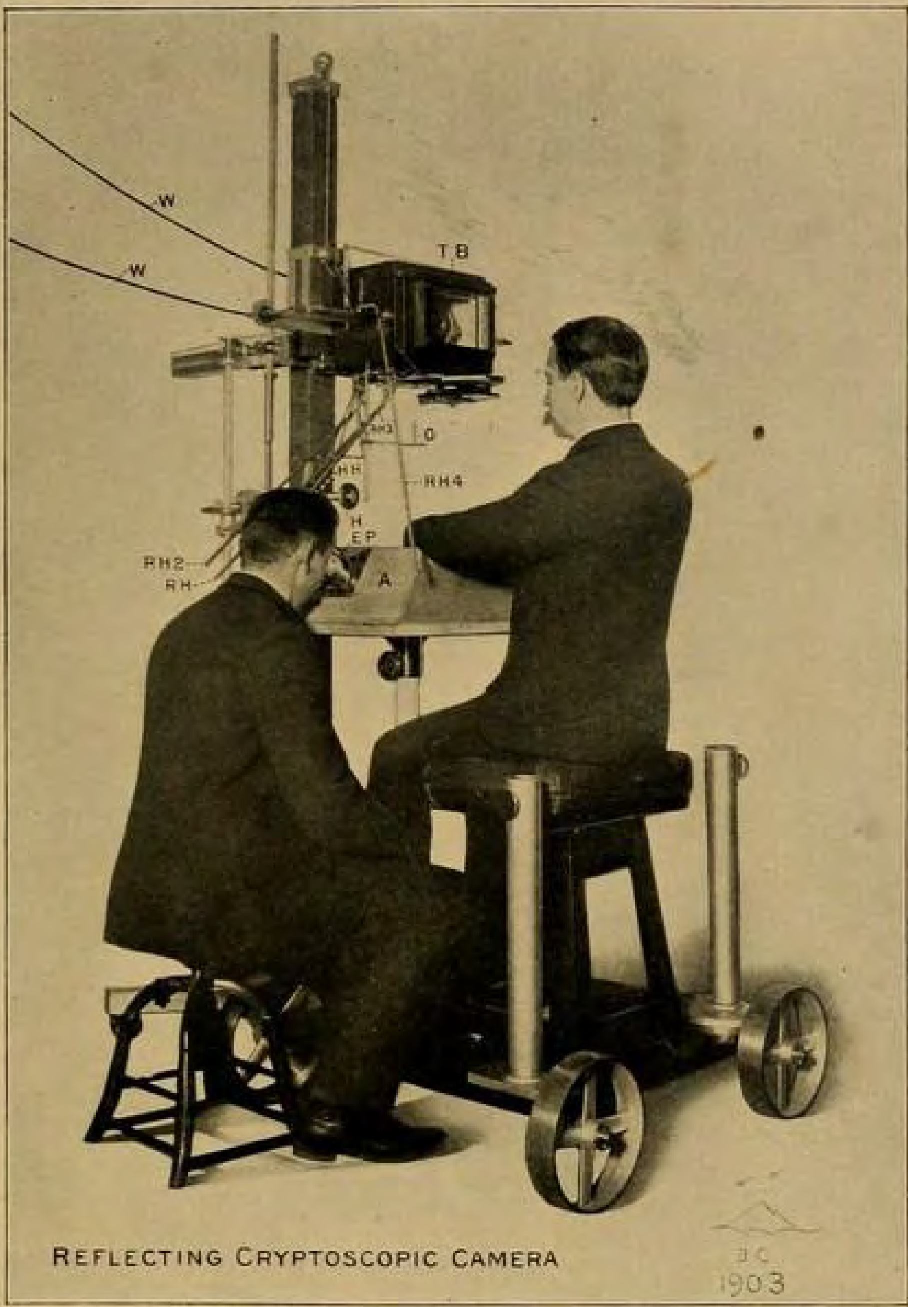

PHF
PN
B
HA
OF
HA
G
SA2
S2
A2
R1
TH
R2
A1
S1
SA1

FIG. 2.

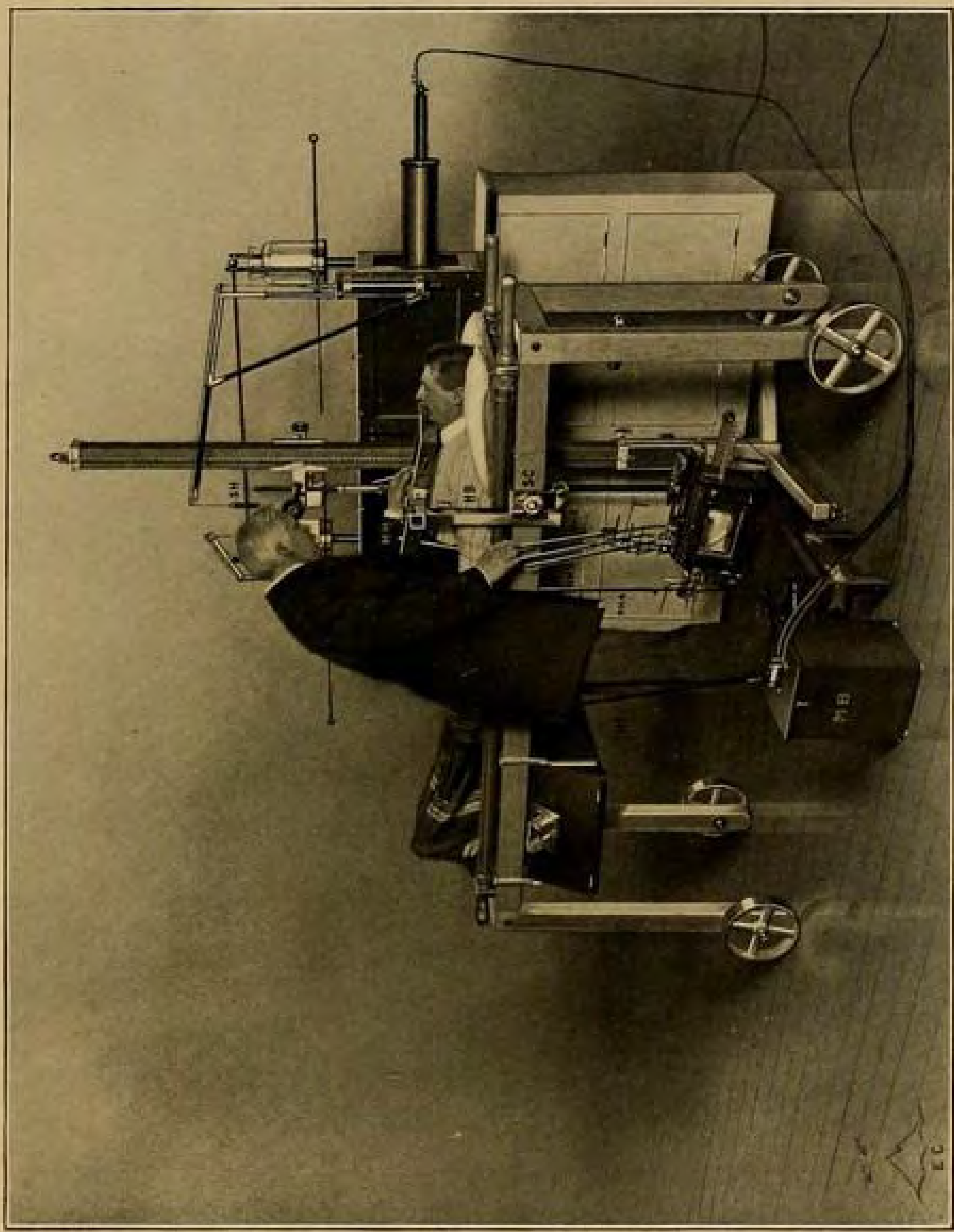
NOTE 162 — FIGURE 6 — PHOTOGRAPHING THE HANDS FOR SIGNALMENT



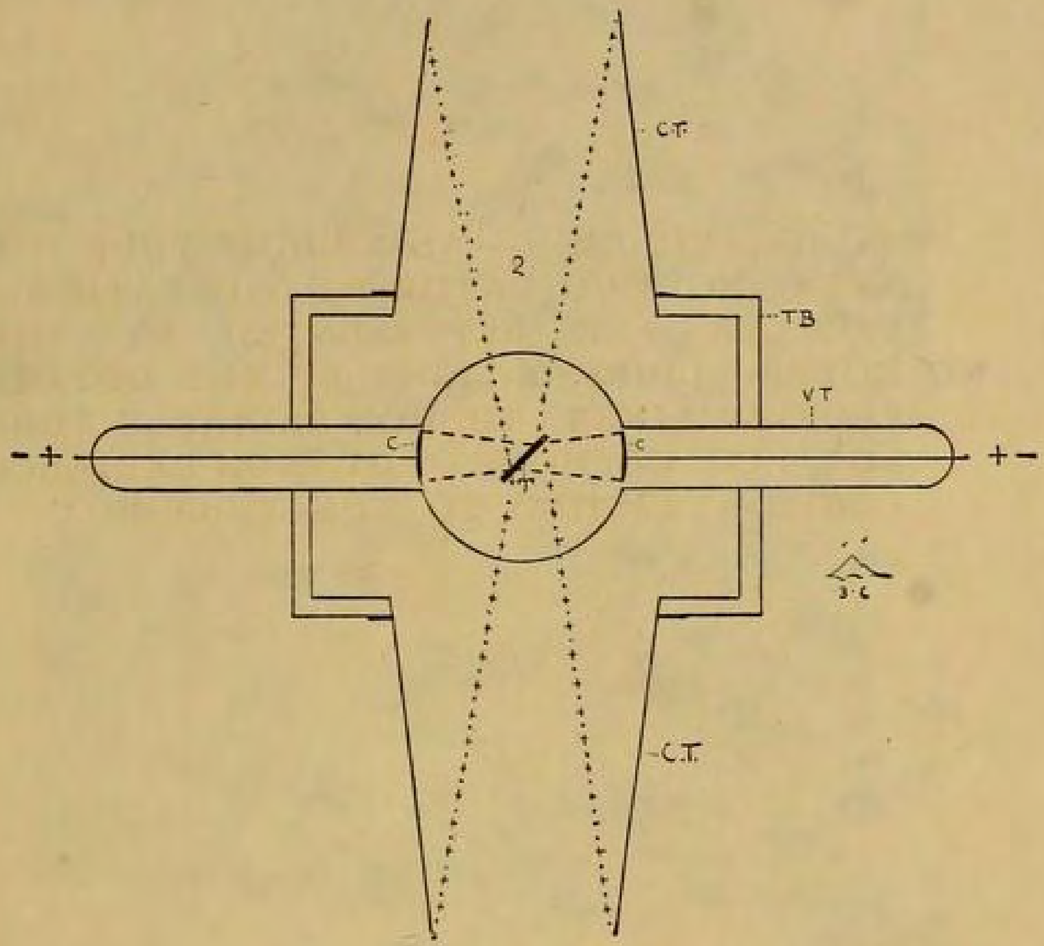
REFLECTING CRYPTOSCOPIC CAMERA

NOTE 162 — FIGURE 8 — A METHOD OF USING A TRACING FRAME IN EXAMINING THE CHEST WHEN THE PATIENT IS IN A HORIZONTAL POSITION

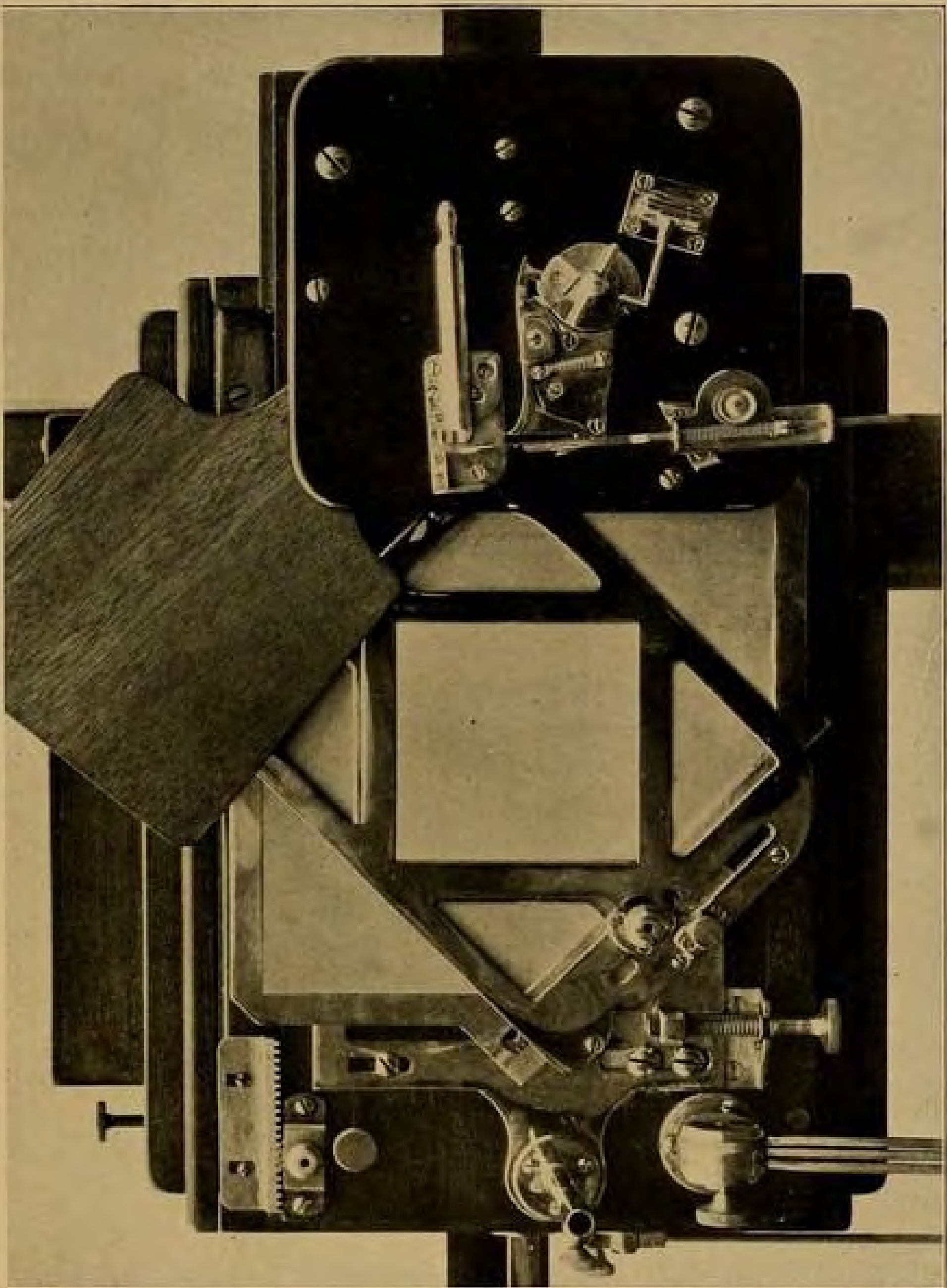
The tracing frame is attached to the side rail of the examination table by the sliding clamp SC. It can be adjusted in height by the bar HB. It turns on a pivot P to allow it to fit the patient's chest, and can be clamped in any position by the milled head MH. In one of the axioms mentioned it was stated that the central ray of the beam of X-light used should strike the tracing paper normal with its surface. Apparently this rule has been departed from in the illustration, but this is due to the perspective, the tube box having been placed at the same angle as the tracing paper. In the illustration the physician has one hand on a handle which regulates the size of the opening in the diaphragm plate. Near this are other handles, whose use has been fully described in other illustrations. Standing up from the break MB is a handle BH, which allows the amount of current to be varied by the physician without interrupting the examination.



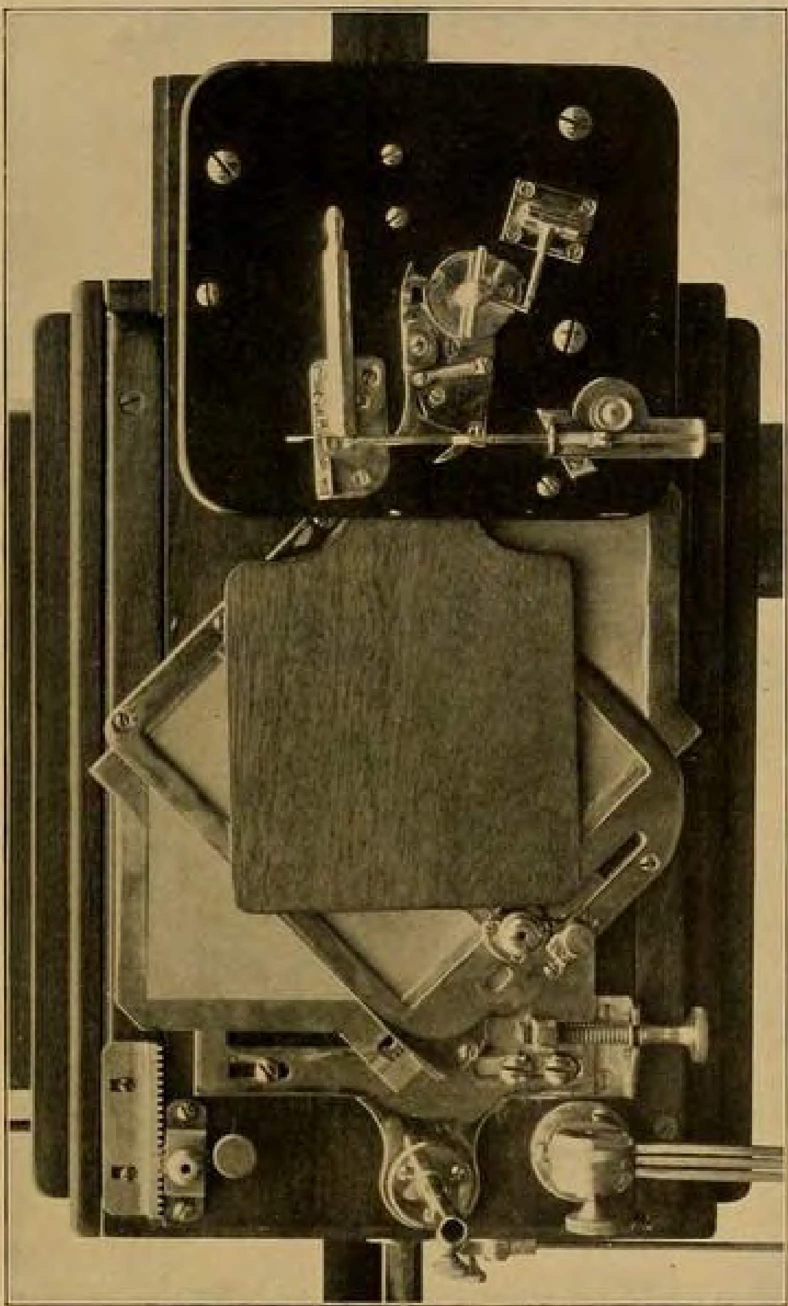
NOTE 168 — FIGURE 1 — AN X-LIGHT TUBE FOR TREATING TWO PATIENTS. THE CATHODE STREAMS ARE REPRESENTED BY THE DOTTED LINES; X-LIGHT BY THE DOTTED CROSSED LINES. TB, NON-RADIABLE TUBE BOX. CC, CATHODES. CT, NON-RADIABLE CONES ATTACHED TO THE TUBE BOX


C.T.
2
TB
VT
-+
C
C
+-
C.T.

NOTE 169 — FIGURE 1 — A SHUTTER FOR AN X-LIGHT TUBE BOX, OPEN



NOTE 169 — FIGURE 2 — A SHUTTER FOR AN X-LIGHT TUBE BOX, CLOSED



NOTE 169 — FIGURE 3 — BACK OF A SHUTTER FOR AN X-LIGHT TUBE BOX

NOTE 169 — FIGURE 4 — A SPIRAL SPRING FOR MOVING AN X-LIGHT TUBE-BOX SHUTTER

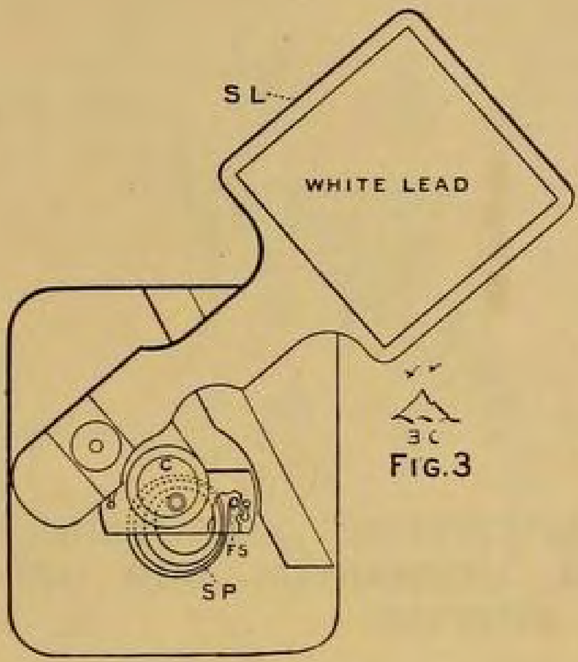


FIG. 3

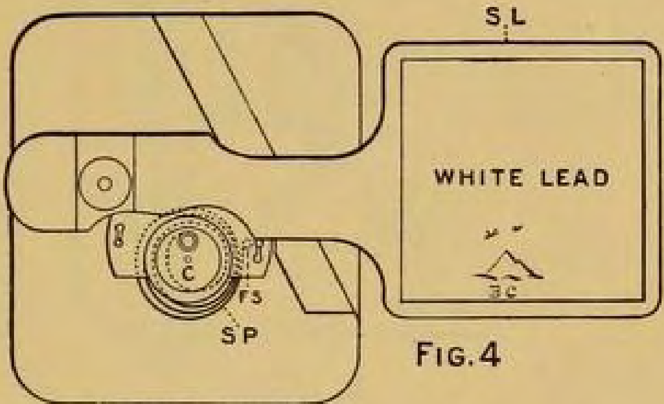


FIG. 4

NOTE 169 — FIGURE 5 — DETAILS OF THE SPRING MECHANISM FOR AN X-LIGHT TUBE SHUTTER

NOTE 169 — FIGURE 6 — POSITION OF THE MECHANISM WHEN OPENING THE X-LIGHT TUBE SHUTTER

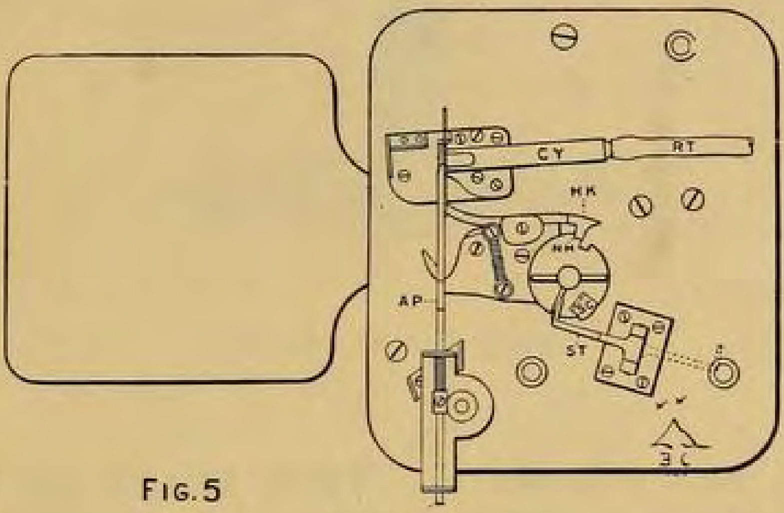


FIG. 5

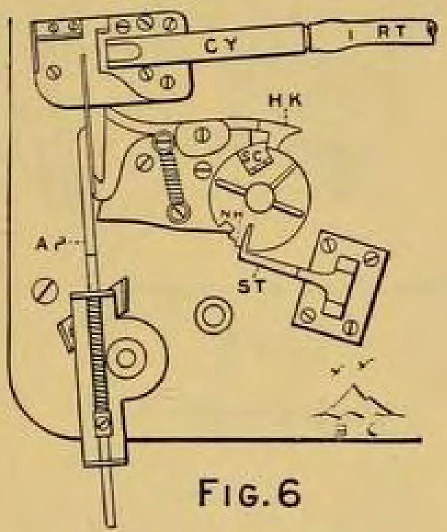
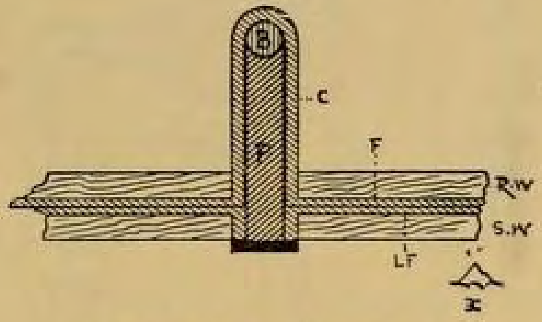


FIG. 6

NOTE 162 — FIGURE 7 — PIVOT PLATE OF THE X-LIGHT WAGON SHOWN ON PLATES 117 AND 121

NOTE 169 — FIGURE 7 — POSITION OF THE MECHANISM WHEN CLOSING X-LIGHT TUBE SHUTTER



Note 162 — Figure 7

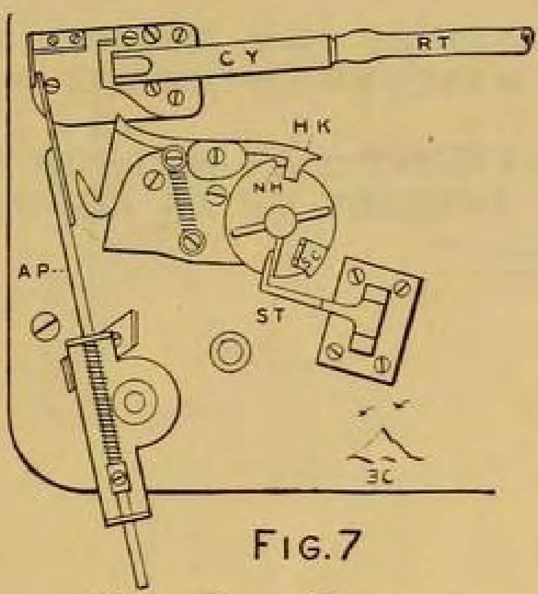


FIG. 7

Note 169 — Figure 7

NOTE 170 — FIGURE 1 — AN ORDINARY FORM OF A MERCURY PUMP

NOTE 170 — FIGURE 2 — A METHOD FOR KEEPING THE MERCURY OF AN AIR PUMP DRY

NOTE 170 — FIGURE 3 — A METHOD FOR KEEPING THE MERCURY OF AN AIR PUMP DRY

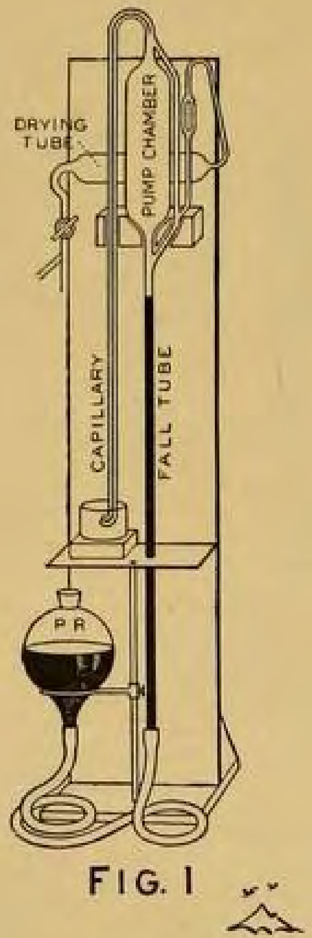
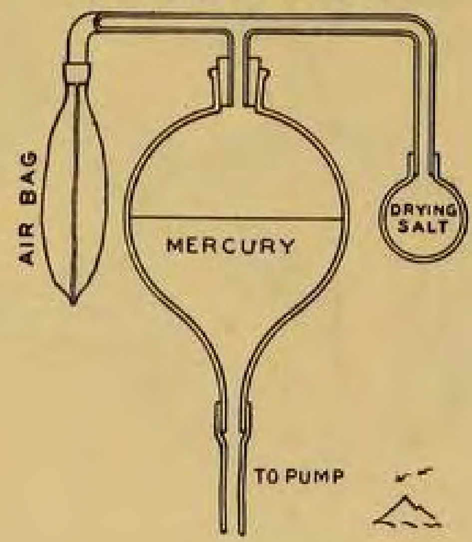


FIG. 1

FIG. 2
PUMP RESERVOIR



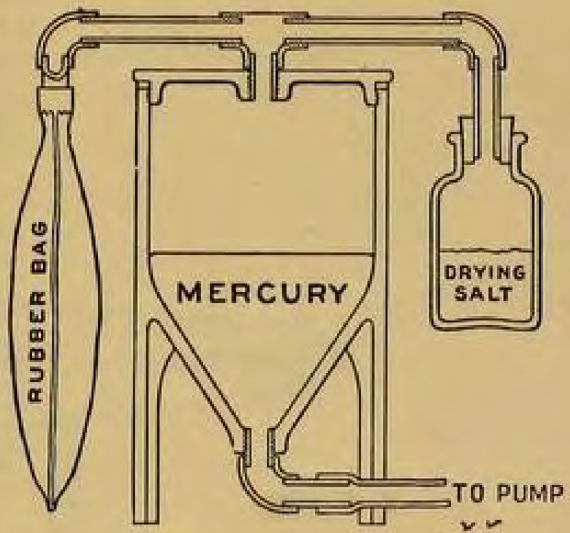
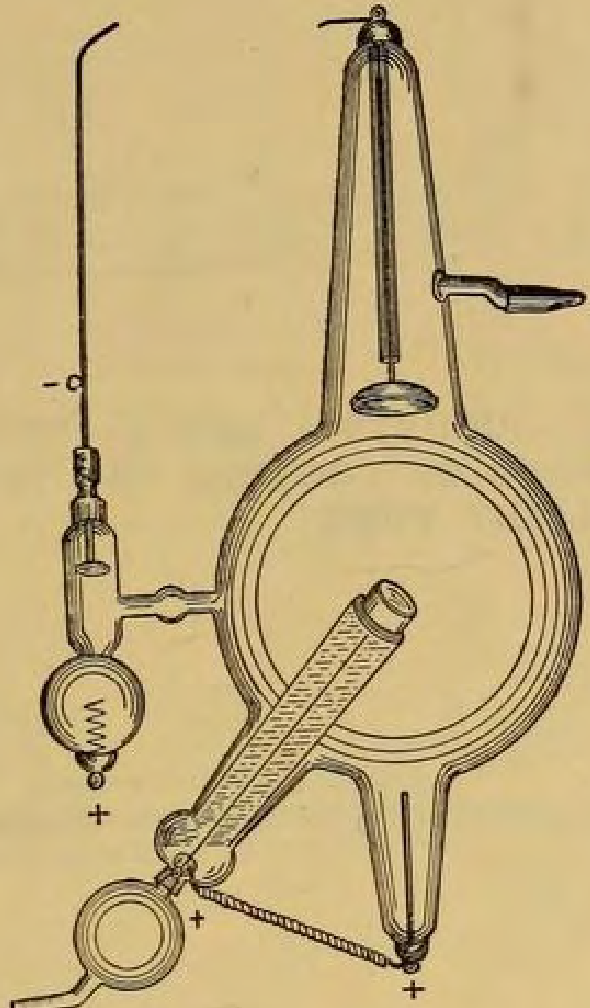


FIG. 3

NOTE 171—FIGURE 1—A DEFECTIVE TYPE OF A COOLED X-LIGHT TUBE



NOTE 171—FIGURES 2 AND 3—DETAILS OF A METHOD OF COOLING THE TARGET OF AN X-LIGHT TUBE

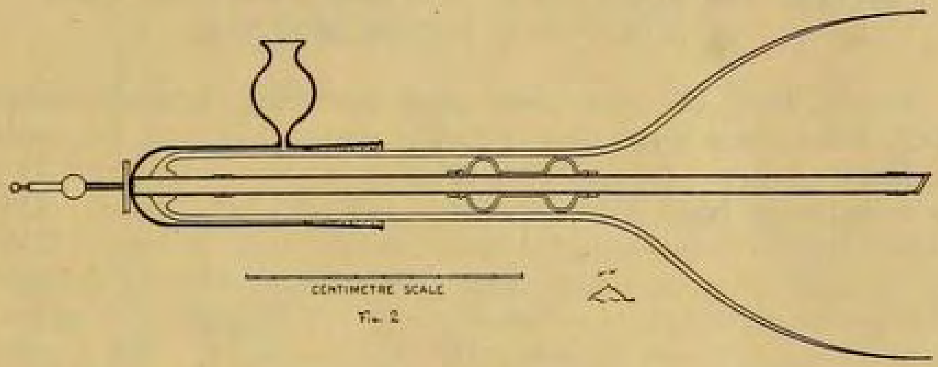


Fig. 2

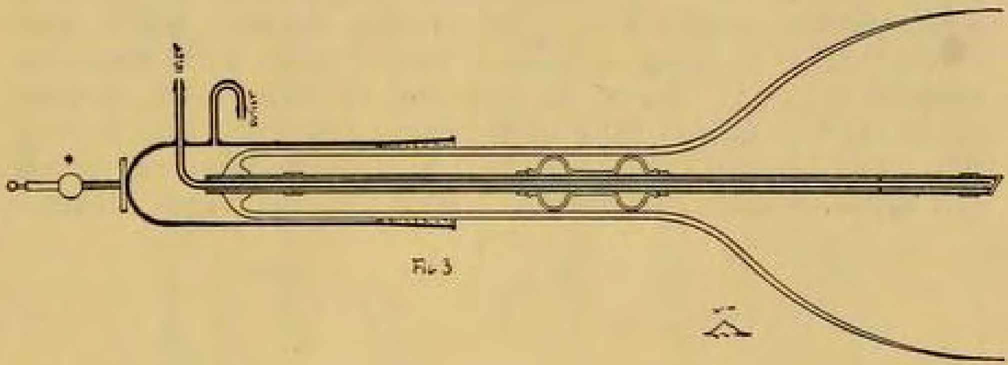
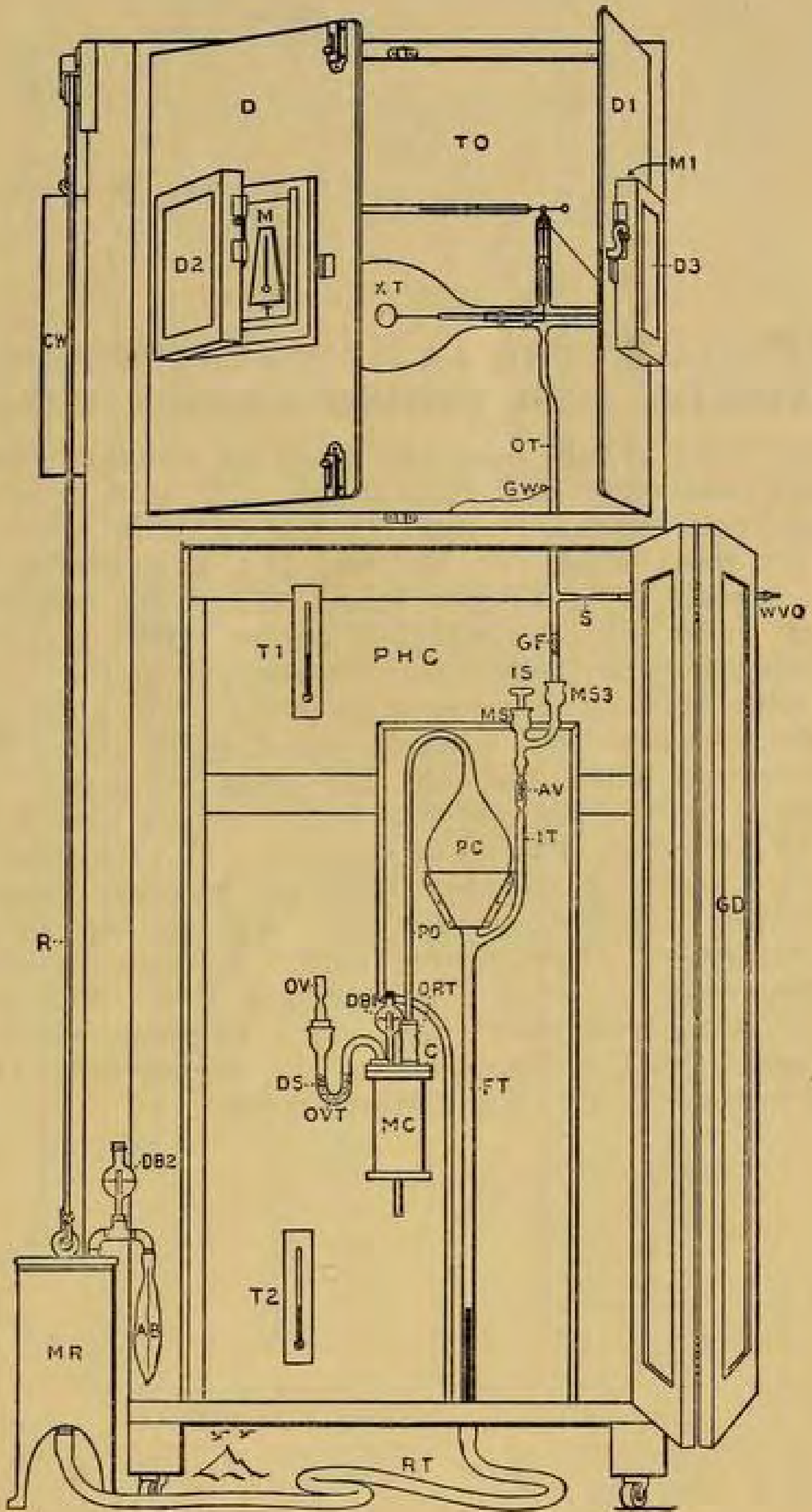


Fig. 3

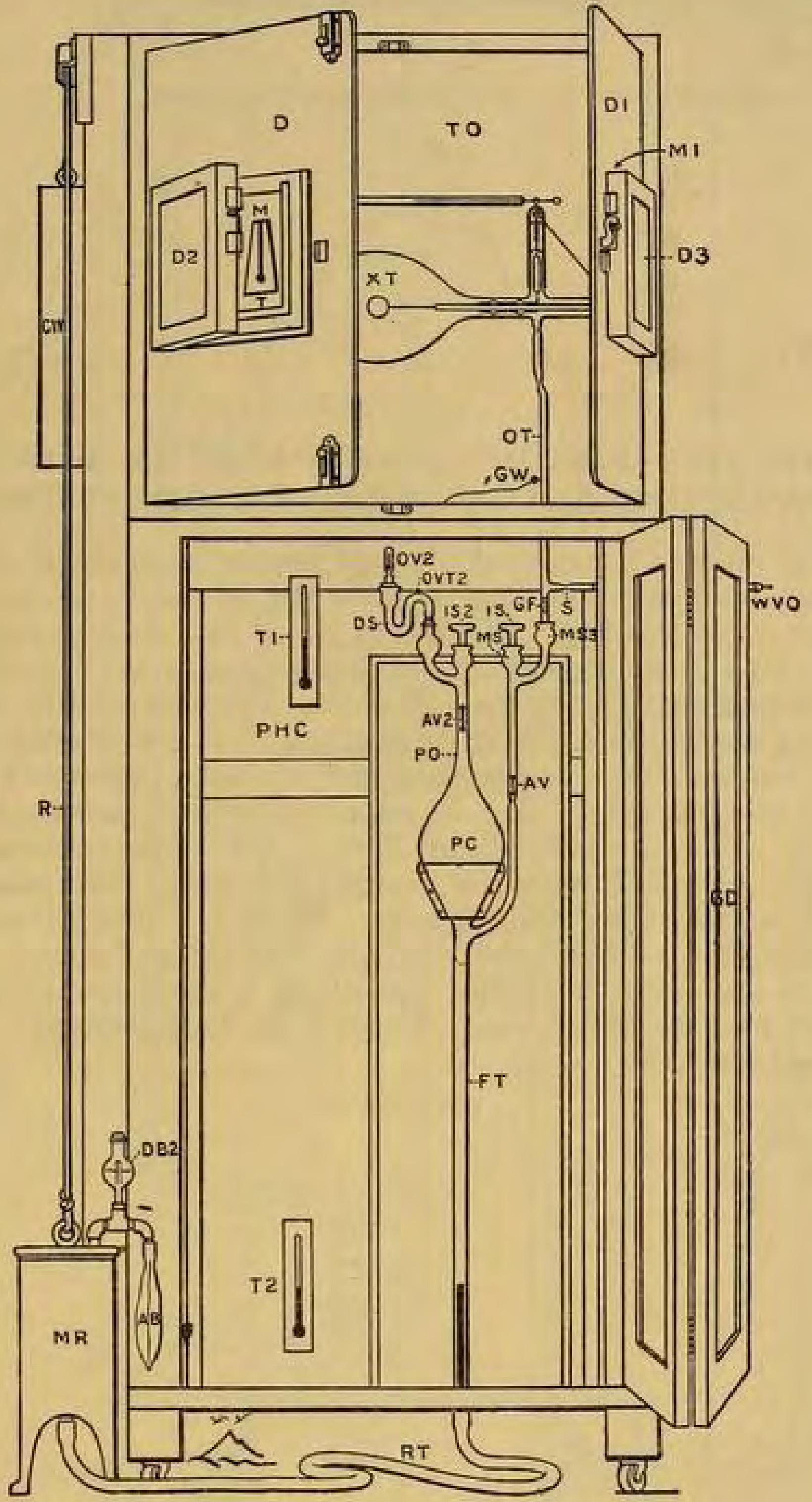
NOTE 173 — FIGURE 2 — APPARATUS FOR PRODUCING HIGH VACUA

Front view of tube oven and pumping arrangements. TO, tube oven with non-radiable walls. D and DI, non-radiable doors. M and MI, mica windows. D 2 and D 3, non-radiable lead glass doors. XT, X-light tube. OT, tube connecting X-light tube with the pump. GW, grounding wire on outlet tube. S, tube connecting X-light tube with mechanical exhaust pump. GF, gold foil to prevent mercury from entering the X-light tube. MS 3, mercury seal where tube OT joins pump. AV, automatic valve. IS, stopcock with mercury seal MS on inlet of pump. PC, Pump chamber. FT, fall tube connecting pump chamber with mercury reservoir MR, through rubber tube RT. AB, air bag on mercury reservoir. DB 2, drying bulb. R, rope connecting mercury reservoir with counterweight CW. PO, pump outlet. ORT, soft rubber tube connecting pump outlet tube with mercury cistern MC. C, cover of mercury cistern. DB, drying bulb. OVT, outlet tube of mercury cistern. DS, drying salt. OV, outlet valve. T, T 1, T 2, thermometers, which can be read from the outside. PHC, pump warm closet.


D
TO
D1
M1
M
D2
D3
X.T
T
CW
OT
GW
S
WVO
GF
T1
PHC
IS
MS3
MS
AV
IT
PC
GD
R
PO
OV
DB
ORT
C
DS
FT
OVT
MC
DB2
T2
AB
MR
RT

NOTE 173 — FIGURE 2 A — APPARATUS FOR EXHAUSTING AND TUNING X-LIGHT TUBES

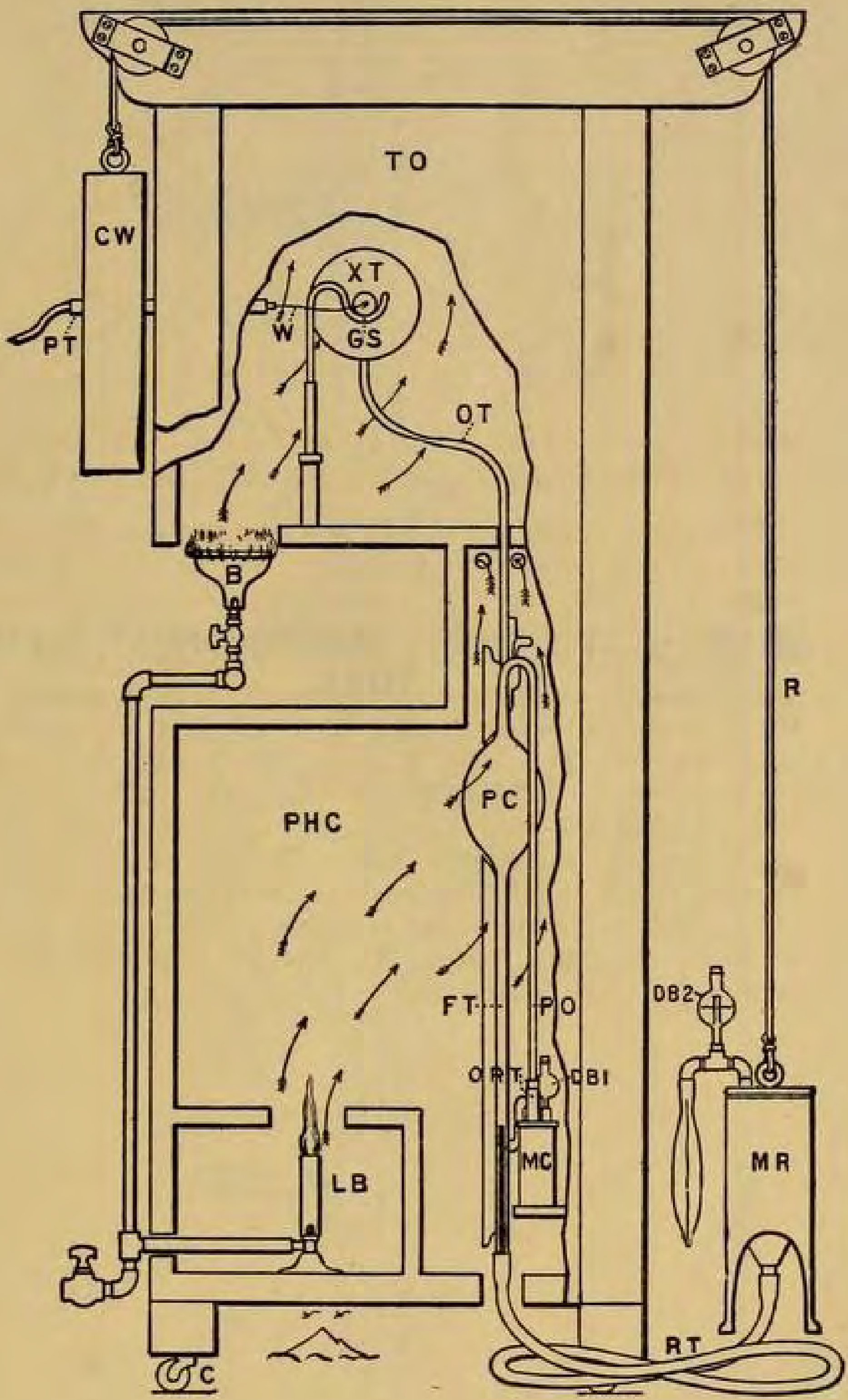
Front view of tube oven and pumping arrangements for routine exhaustion of X-light tubes. TO, tube oven with non-radiable walls. D and DI, non-radiable doors. M and MI, mica windows. D 2 and D 3, non-radiable lead glass doors. XT, X-light tube. OT, tube connecting X-light tube with the mercury pump. GW, grounding wire on the outlet tube. S, tube connecting the X-light tube with the mechanical exhaust pump. GF, gold foil to prevent mercury from entering the X-light tube. MS 3, mercury seal where the tube OT joins the pump. AV, automatic valve. IS, stopcock with mercury seal MS on inlet of the pump. PC, pump chamber. FT, fall tube connecting the pump chamber with the mercury reservoir MR through the rubber tube RT. AB, air bag on mercury reservoir. DB 2, drying bulb. R, rope connecting mercury reservoir with counterweight CW. PO, pump outlet. AV 2, automatic valve. IS 2, stopcock with mercury seal. OVT 2, drying tube. DS, drying salt. OV 2, outlet valve. T, T 1, T 2, thermometers.



D
TO
D1
M1
D3
D2
M
T
XT
CW
OT
GW
OV2
OVT2
T1
DS
IS2
IS
GF2
S
MS
MS3
WVO
PHC
AV2
PO
AV
R
PC
GD
FT
DB2
T2
AB
MR
RT

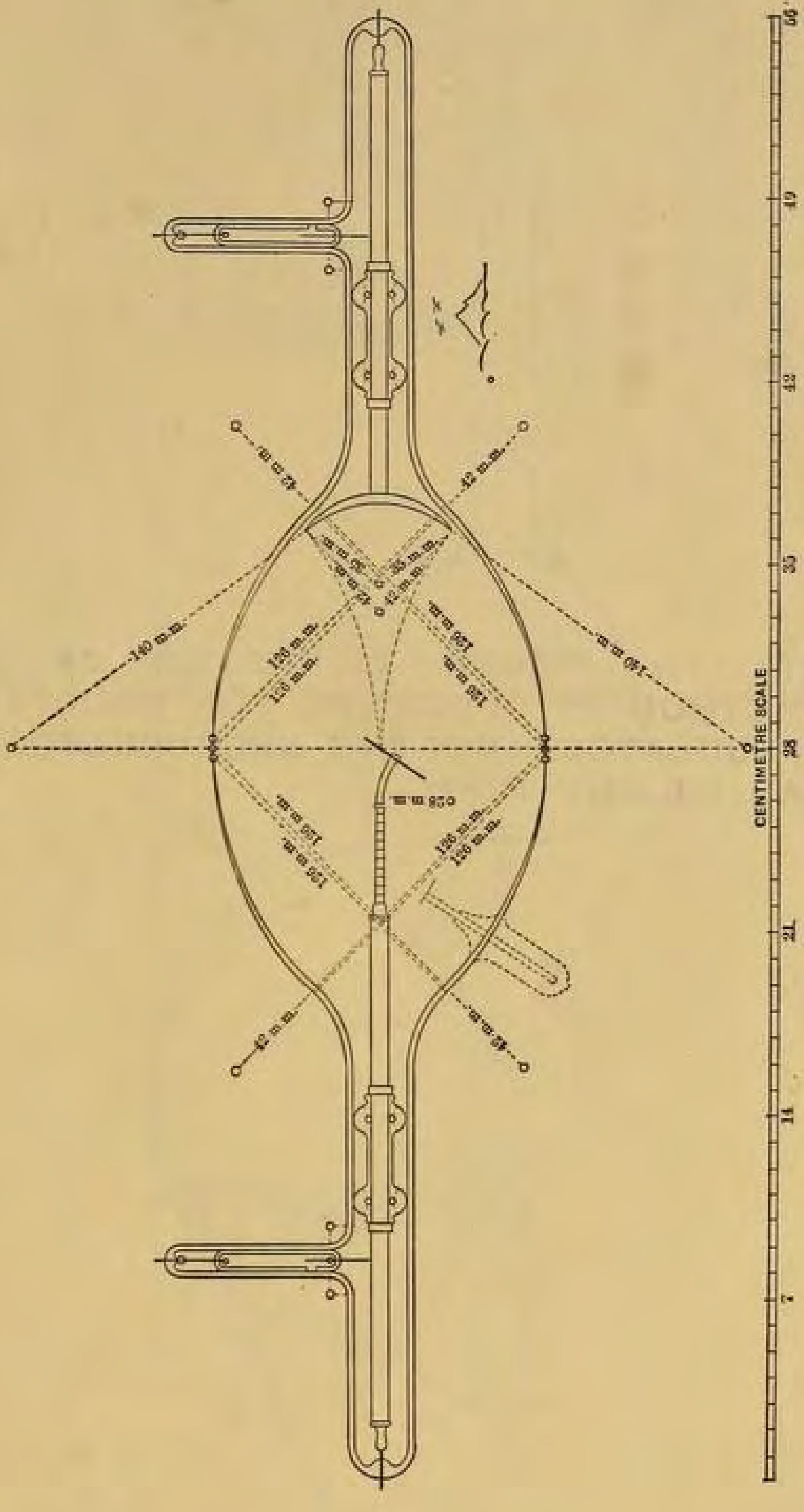
NOTE 173 — FIGURE 3 — APPARATUS FOR EXHAUSTING AND TUNING X-LIGHT TUBES

Side view of tube oven, TO, and pump warm closet, PHC, with sides partly removed to show the interiors. B and LB, burners for heating. PC, pump chamber. PO, pump outlet. MC, mercury cistern on pump outlet to which it is connected air tight by the soft rubber cylinder, ORT. DBI, drying bulb. MR, mercury reservoir. DB 2, drying bulb. RT, rubber tube connecting the mercury reservoir MR with the fall tube FT. R, rope connecting mercury reservoir with counterweight CW. OT, tube connecting X-light tube XT with the pump. GS, glass fork supporting one end of the X-light tube. W, one of two wires connecting the X-light tube with the electric generator. PT, one of two porcelain tubes insulating wires from the metal walls of the tube oven. C, one of four castors. The arrows indicate heated air.

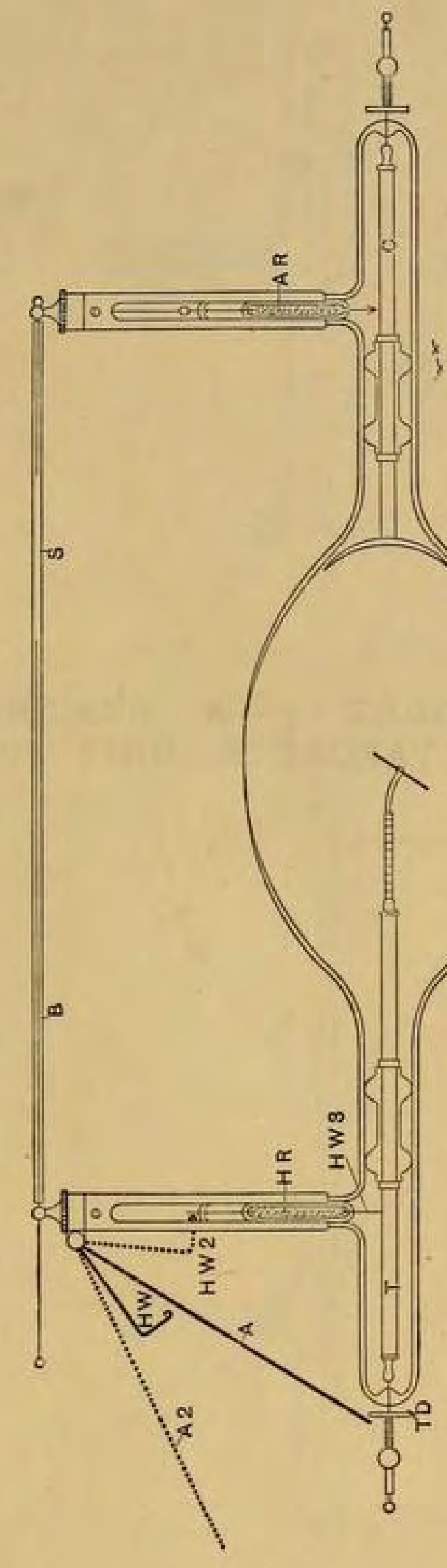

TO
CW
XT
PT
W
GS
OT
B
R
PC
PHC
FT
PO
DB2
ORT
DBI
MC
MR
LB
RT
C

NOTE 175 — FIGURE 1 — DESIGNING AN X-LIGHT TUBE

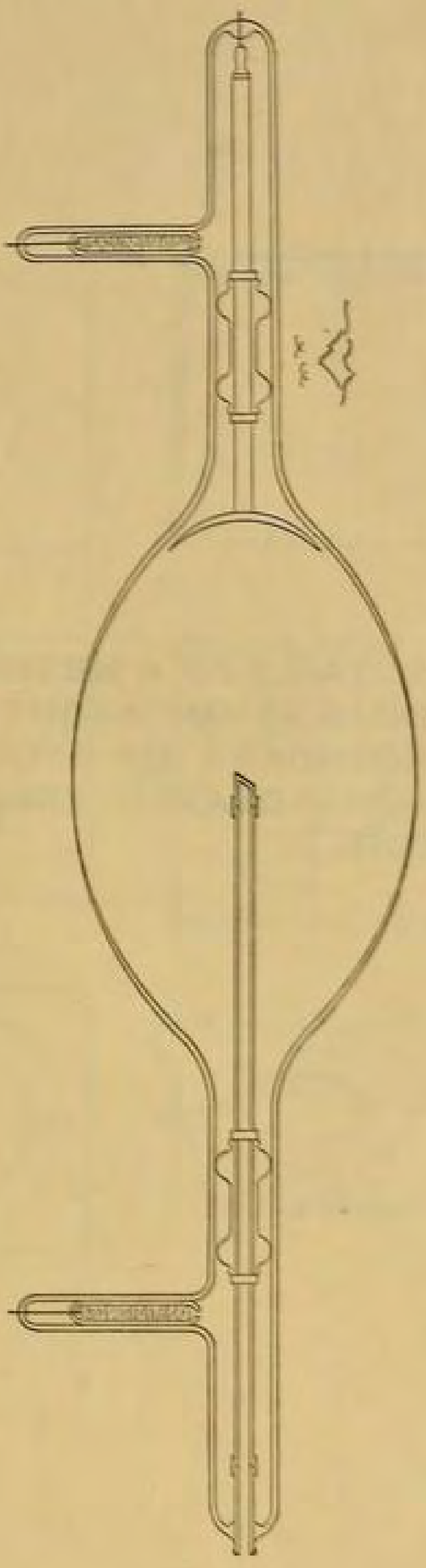
Plate 135



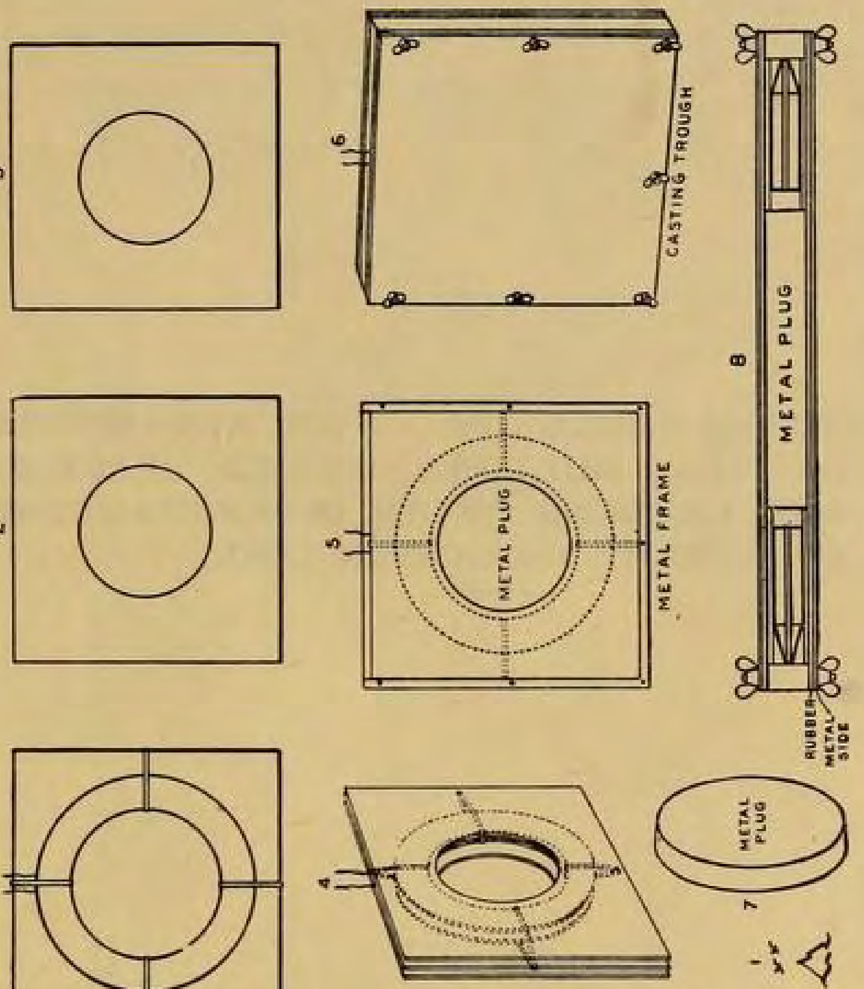
NOTE 175 — FIGURE 2 — DETAILS OF THE METHOD OF OPERATING THE RESISTANCE REGULATOR AND THE REGENERATOR OF AN X-LIGHT TUBE


AR
C
S
B
HR
HW3
HW2
HW
A
T
TD
A2

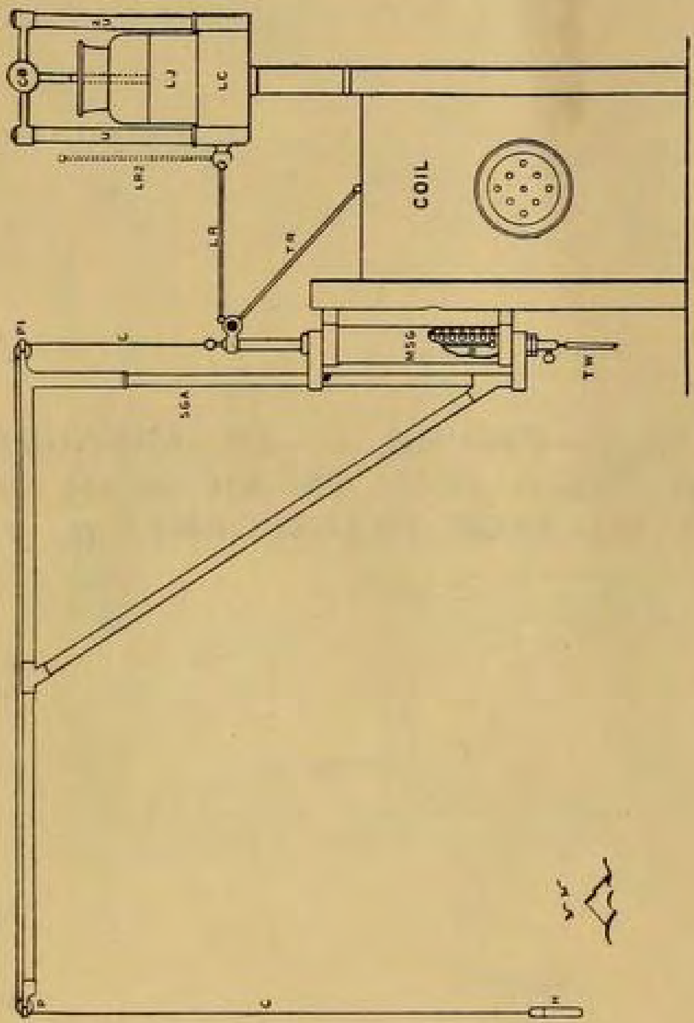
NOTE 175—FIGURE 3—A DESIGN FOR A COOLED TARGET X-LIGHT TUBE



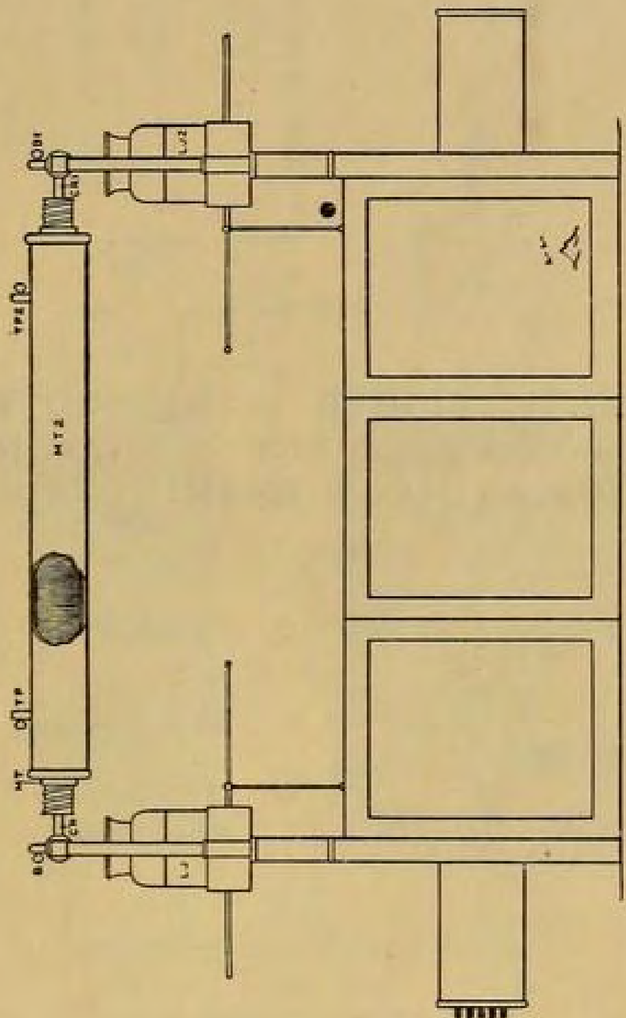
NOTE 179 A — DETAILS OF A METHOD OF CASTING THE INSULATION ABOUT A SECTION OF THE SECONDARY OF THE INDEPENDENT INTERCHANGEABLE SECONDARY INDUCTION COIL


1
2
3
4
5
6
7
8
METAL PLUG
METAL FRAME
CASTING TROUGH
METAL PLUG
RUBBER
METAL
SIDE
METAL PLUG

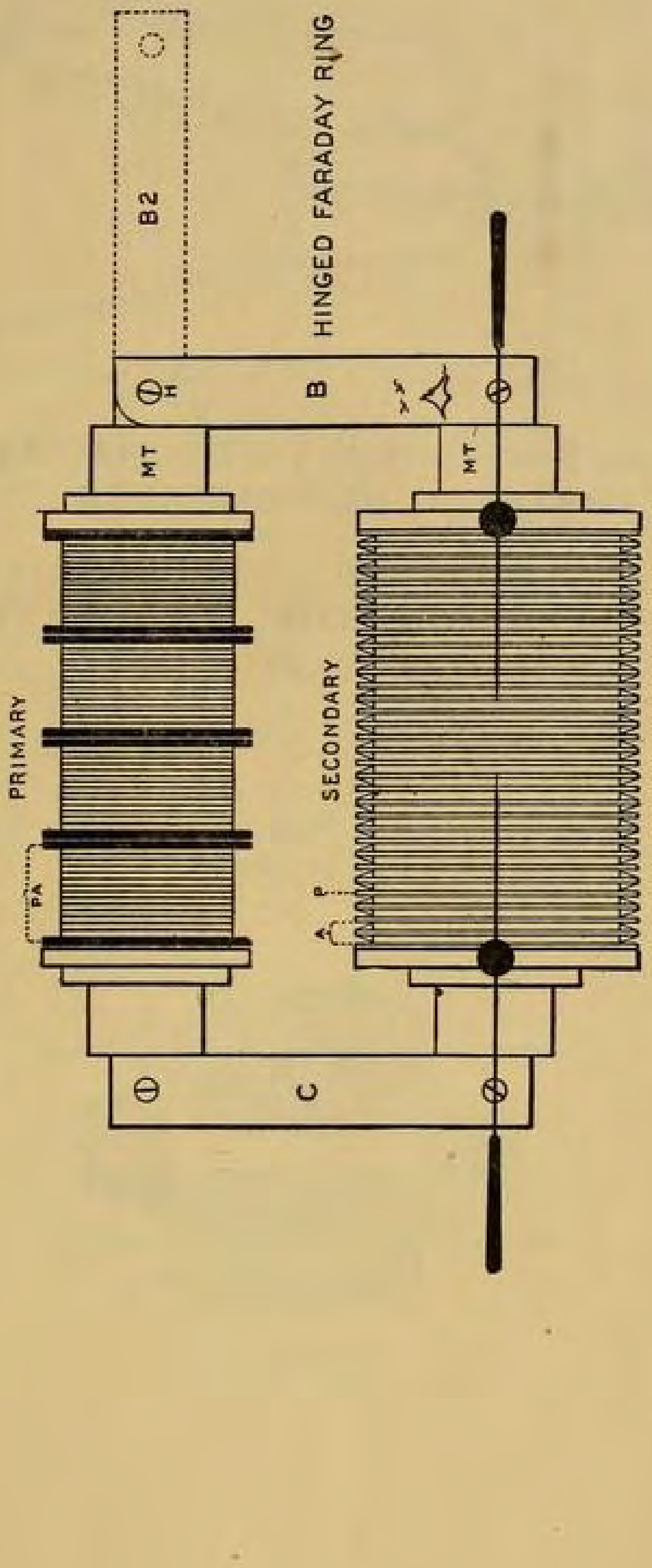
NOTE 179 B — FIGURE 1 — AN ARRANGEMENT OF THE MULTIPLE SERIES SPARK-GAPS AND LEYDENS OF AN INTERCHANGEABLE SECONDARY INDUCTION COIL


COIL
LJ
LC
MSG
SGA

NOTE 179 B — FIGURE 2 — AN ARRANGEMENT OF A TESLA COIL ON AN OPEN CIRCUIT HIGH VOLTAGE TRANSFORMER



NOTE 179 D — FIGURE 1 — HINGED FARADAY RING FOR ETHER AND ELECTRON THERAPEUTICS AND FOR EXAMINING MINERALS


B2
HINGED FARADAY RING
H
B
MT
MT
PRIMARY
SECONDARY
PA
A
P
C

NOTE 179 D — FIGURE 2 — DERMA-RAY TUBE IN A PORTABLE NON-RADIABLE HOLDER

NOTE 179 D — FIGURE 3 — A FARADAY RING WITH A HINGE, THE SECONDARY WITH INTERCHANGEABLE SECTIONS

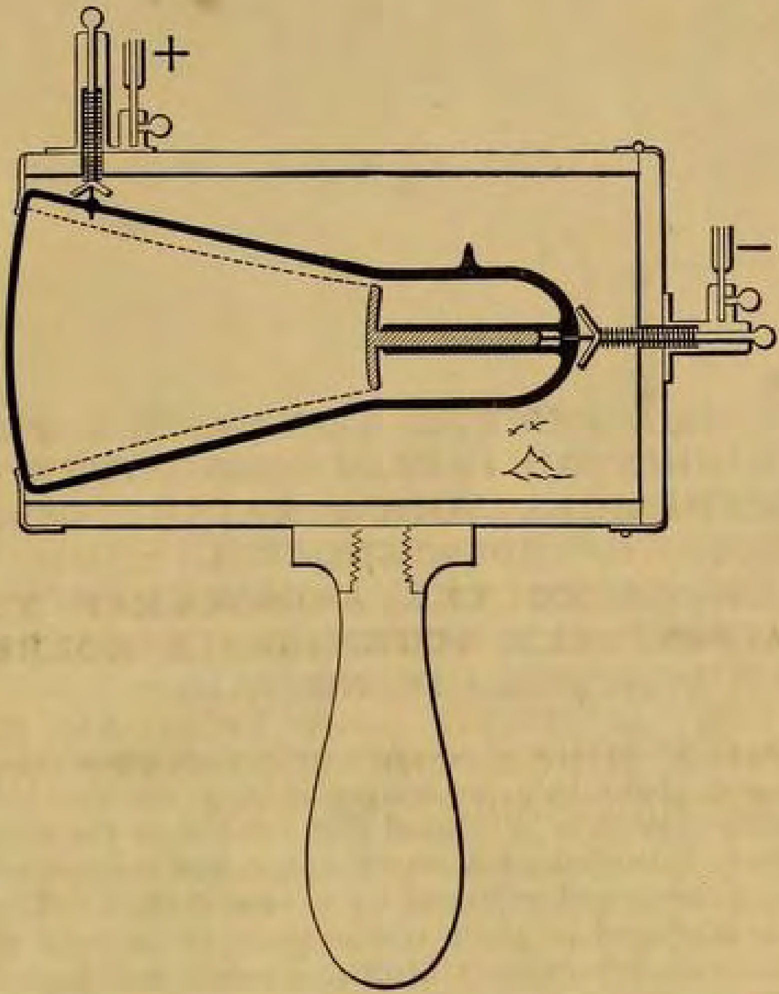


Figure 2

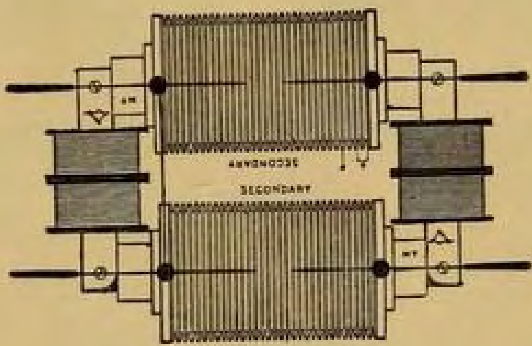


Figure 3

NOTE 179 D — FIGURE 4 — VARIABLE POTENTIAL HINGED FARADAY RING WITH TWO SECONDARIES, WHICH MAY BE USED IN SERIES OR INDEPENDENTLY AND PROVIDED WITH THE ARRANGEMENTS FOR VARYING THE POTENTIAL ILLUSTRATED AND DESCRIBED IN NOTE 112

Each section of the secondary is independent of the others and of the tube separating it from the core; therefore when a section is injured the end bar of the coil may be unlocked, turned back on its hinge, the injured section easily removed and replaced by a new section. The primary is arranged to allow the sections to be used singly, in series, or otherwise. Multiple series spark-gaps enable the vacuum tubes to be operated over a considerable range in resistance.

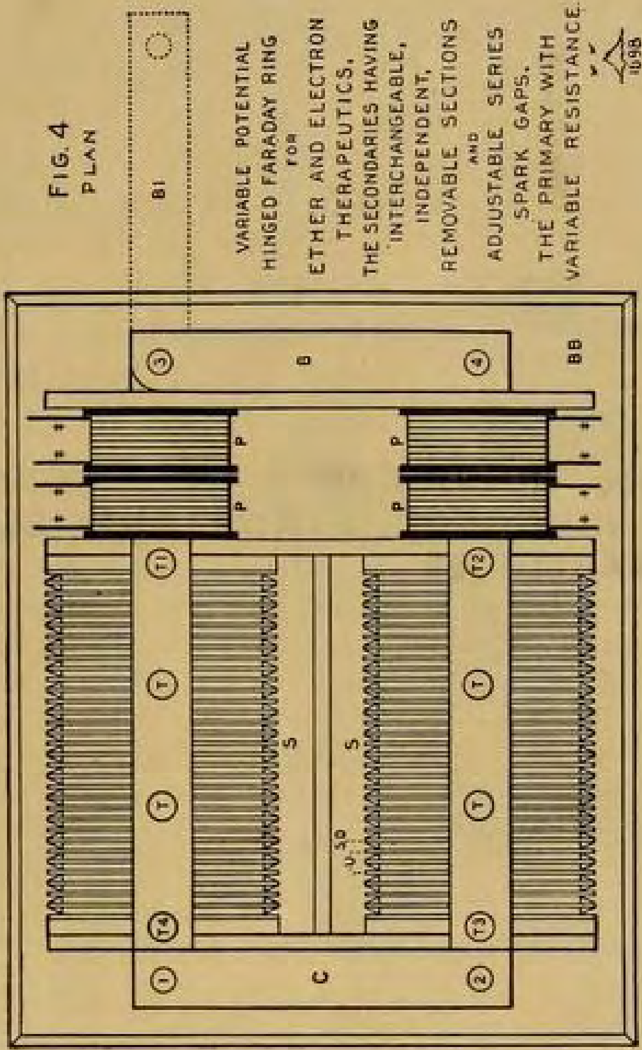


FIG. 4
PLAN

VARIABLE POTENTIAL
HINGED FARADAY RING
FOR
ETHER AND ELECTRON
THERAPEUTICS,
THE SECONDARIES HAVING
INTERCHANGEABLE,
INDEPENDENT,
REMOVABLE SECTIONS
AND
ADJUSTABLE SERIES
SPARK GAPS.
THE PRIMARY WITH
VARIABLE RESISTANCE.

1898

NOTE 179 D—FIGURE 5—A HINGED FARADAY RING FOR ETHER AND ELECTRON THERAPEUTICS

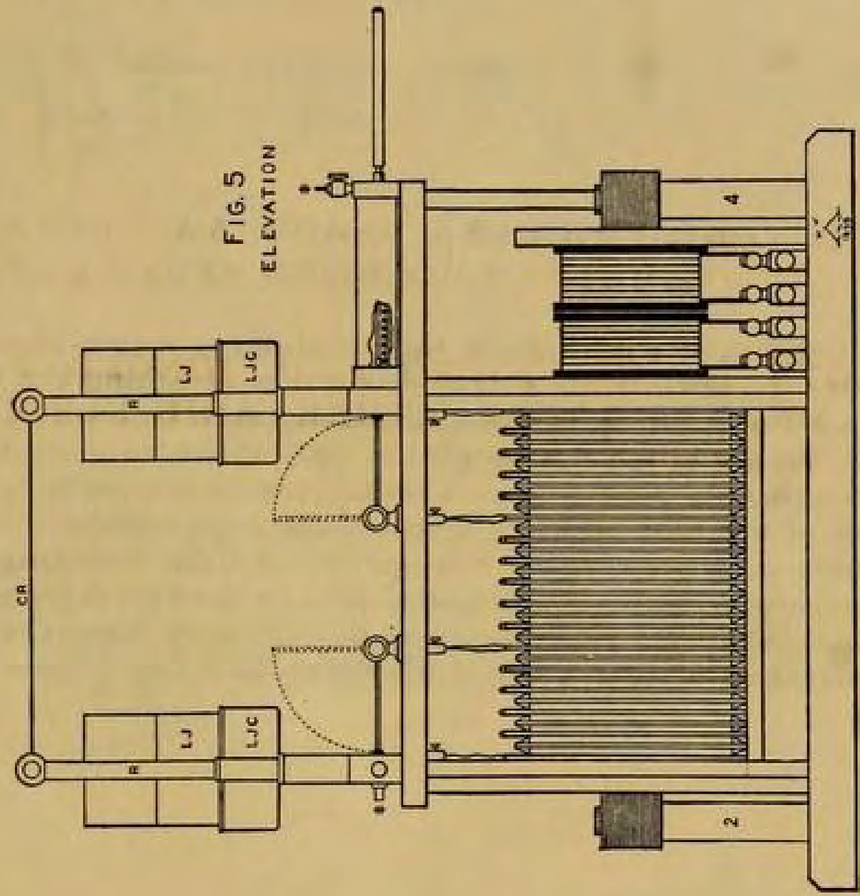


FIG. 5
ELEVATION

NOTE 179 D — FIGURES 6 AND 6 A — DETAILS OF A MULTIPLE SERIES SPARK-GAP

It consists of a micanite tube containing a row of metal balls, as shown in Note 112. Instead of attaching the balls to a strip of mica, as in the illustrations to Notes 112, 137, 140, holes are bored through the wall of the micanite tube, through which pass screws which clamp the balls to the wall of the tube. Multiple series spark-gaps require to be enclosed to prevent the nitrogen acids from irritating the respiratory organs. The gas should be drawn off from the spark-gaps by an aspirator, as described in Note 122 and illustrated in Note 112 and Plate 81, Note 140, Figure 6.

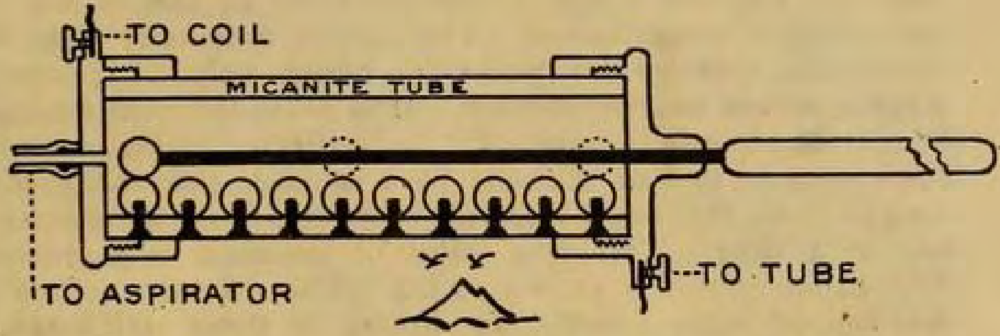


Figure 6

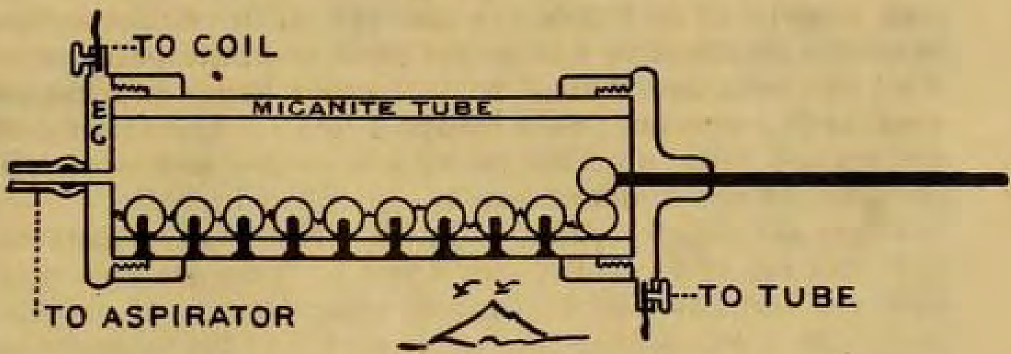
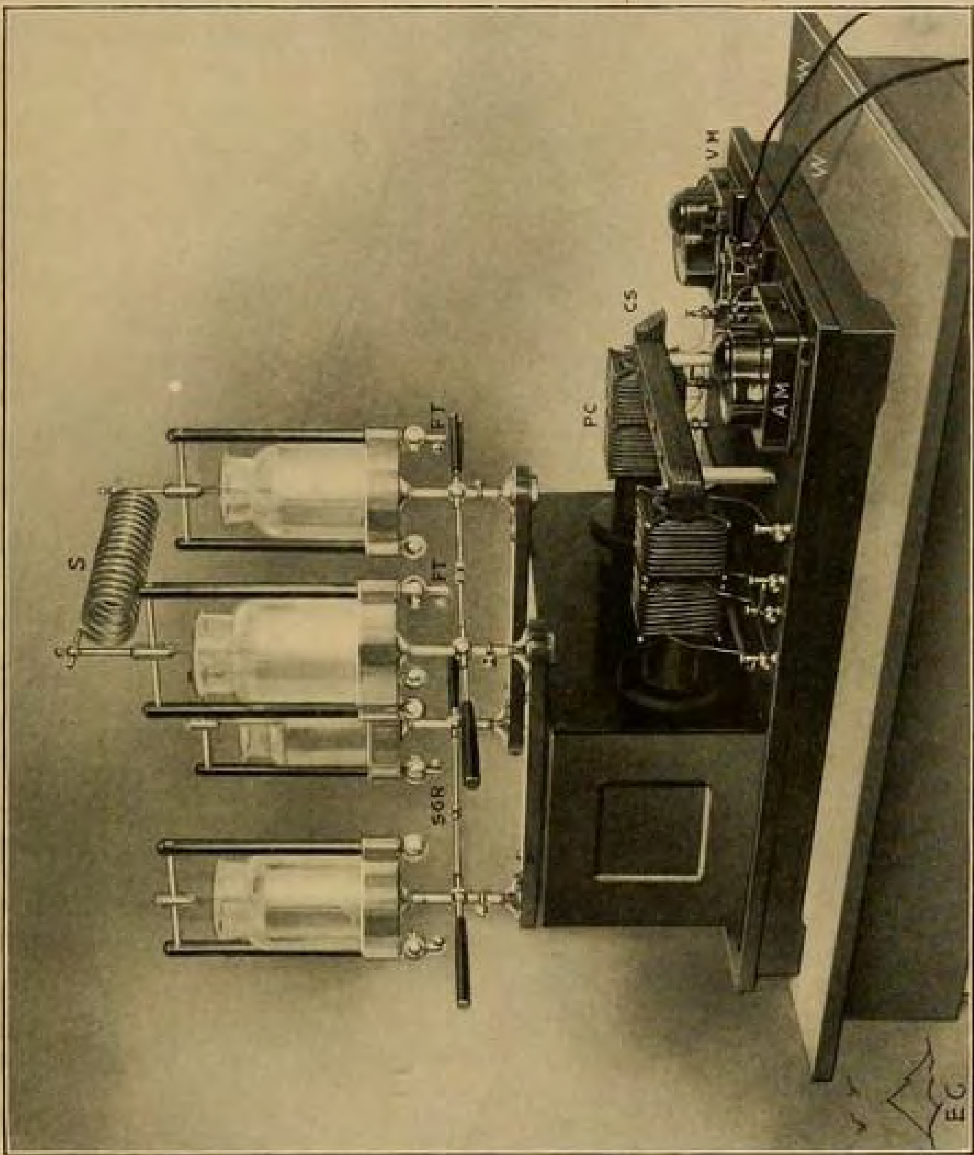


Figure 6A

NOTE 179 D—FIGURE 7—HINGED FARADAY RING FOR ETHER AND ELECTRON THERAPEUTICS WITH THE SECONDARY SECTIONS IN SERIES

This transformer is of the type illustrated in Plates 143 and 144, Figures 4 and 5, though some of the details of construction are different. The core is unusually light to make the transformer portable, being only four centimetres square in cross-section. It is provided with a hinge like those already illustrated. To facilitate closing, each of the plates of one of the side bars is made one millimetre longer than the next, allowing the sheets to be inserted one at a time. This is a point of practical importance. The construction is shown at CS. The primary coils PC are wound more openly, air spaces of three millimetres being left between the layers and between the strands of each layer, to allow of a larger current being used without injurious heating. The primary contains four coils, each having forty-nine turns of number ten copper wire. The secondary contains thirty-eight sections constructed on the plan illustrated in Notes 112 and 137, each section having two coils attached to a micanite plate one millimetre thick. Half the coils are wound with number thirty-two copper wire, each containing nine hundred turns. The other coils are wound with number thirty-four wire, and each coil contains fifteen hundred turns.

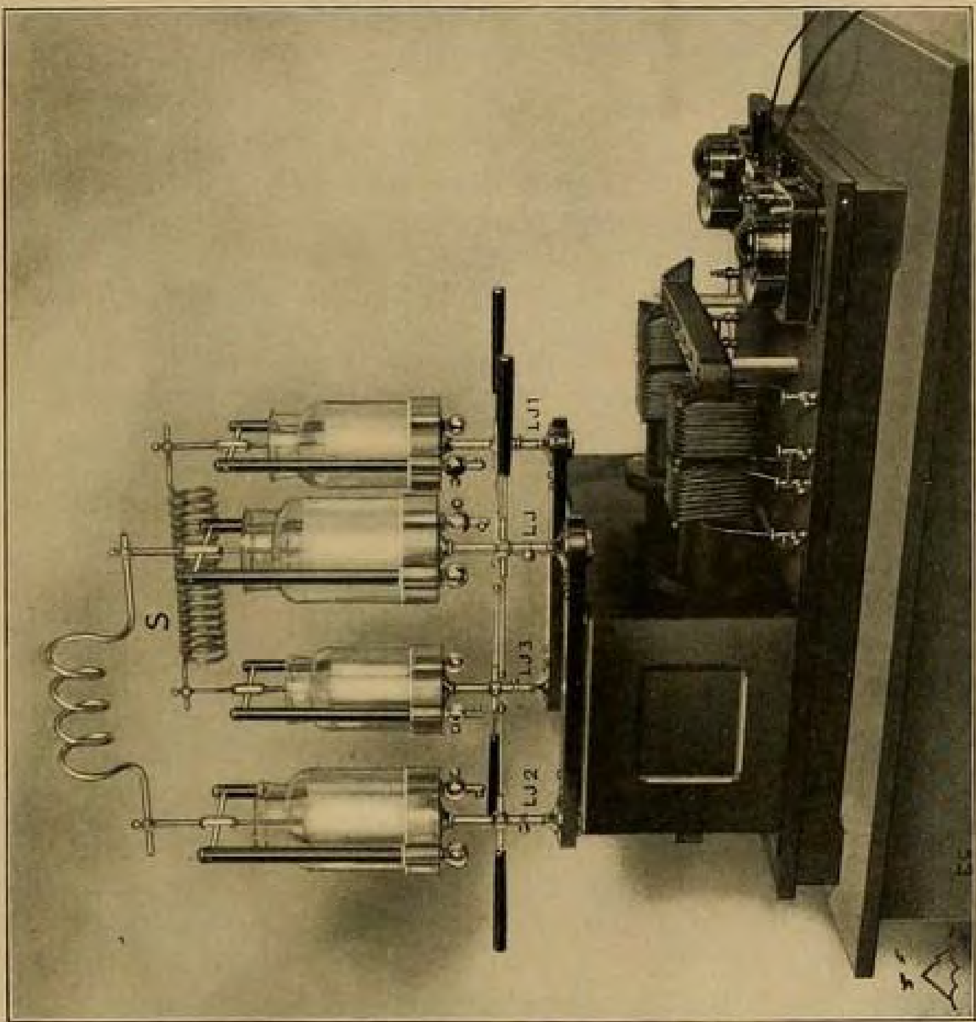
There are four Leydens, as in the transformer illustrated in Plates 143 and 144, Figures 4 and 5. Two are connected with the terminals of the united secondaries. If the vacuum tube is attached to the terminals FT of the secondaries, which are connected by bringing the spark-gap rods SGR together, the transformer has sufficient voltage to excite a double-focus or Roentgen X-light tube and amperage enough to melt even a cooled target, unless it is cooled by a constant circulation, as described in Note 1. It will also excite a single focus or Crookes X-light tube. It is not particularly recommended for exciting any form of X-light tube for diagnosis, because, as already frequently stated, a generator should have a very high voltage for this purpose. For therapeutics the case is different, as quantity is of more importance than ability to regulate the X-light with great nicety. The transformer is useful for exciting derma-ray


S
FT
FT
SGR
PC
CS
VM
AM
W
W

tubes, either of the type shown in Figure 2 or of other types, having two terminals, from both of which cathode streams are sent forward to the wall of the tube nearest the patient, there producing the derma rays by their impact. Little energy is required in the primary of the transformer when it is used for this purpose with a small derma-ray tube. Enough current will pass through a fifty-candle, one hundred and ten volt Edison lamp in series with the primary, or, if the condensers are used, the tube will be lighted with the current, which will pass through a similar thirty-two candle-power lamp. The transformer is valuable for producing the ultra-violet arc for treating lupus. For this purpose a greater current is used in the primary. The arc should be between aluminum terminals. If it is about three millimetres long, it is almost noiseless, and so cool it may be brought almost in contact with the patient's skin. The aluminum, high-voltage arc was recommended in earlier papers as far superior to the low-voltage arc between carbon or iron terminals, because most of the energy of the current is converted into short ether waves, on which we depend for ionizing the tissues to get therapeutic effects, while with the low-voltage arc most of the energy is converted into the long heat waves, which are not useful, and require complicated apparatus to absorb them. For the high-voltage arc the inner coatings of the condensers are connected, otherwise the arc is a pale yellow flame. The transformer is also useful for producing the electron arc mentioned in Note 179. When it is used for this purpose the wires leading to the arc are attached at FT and the inner coatings of the Leydens connected. In this case, also, the energy in the primary should be considerable. Absence of heat and ability to bring the source of electrons in near contact with the patient are valuable features. As it has been shown by the experiments on animals and on man, briefly mentioned in earlier papers, that these electrons have the same therapeutic effects as the beta radium rays, a transformer for producing them should be interesting. The transformer is also valuable when it is desired to subject a patient to rapid polarizations of the ether in his tissues, — such, for example, as is obtained by placing a part or the whole of his body in a solenoid through which alternating currents from the secondary of the Faraday ring are passing. For this work connection is made between the solenoid and the main terminals of the transformer at FT. If more rapid changes in the ether are desired, the inner coatings of the Leydens should be connected by a rod. The transformer was also designed for exciting vacuum tubes to be applied to the skin or to be held near the body in treating internal diseases, — tuberculosis and dilation of the stomach, for example, — the tubes being connected with one pole of a large solenoid whose other pole is attached to one terminal of the secondary, the current returning to the transformer through the ether. Still more rapid ether changes may, of course, be obtained by connecting the solenoid with the terminals of the secondary of the Tesla coils which were designed for this apparatus. These coils, as already stated, will form the subject of a future note, as they require many illustrations and a detailed description. The transformer can be used with direct currents if some form of break is employed. When excited by alternating currents from commercial circuits it is the most convenient source of ultra-violet light, derma rays, X-light, and electrons for examining minerals. As one large enough could be sold for seventy-five dollars, it is hoped some manufacturer will make them commercially available, for no examination of a mineral can be considered to be complete until the specimen has been bombarded by electrons and short ether waves. A transformer of the size illustrated in Figure 1 is large enough for these examinations, and weighs so little it can be easily moved about by one man. A voltmeter VM and an ammeter AM are mounted on the base, as it is important to know the amount of energy employed in the treatment. A fuse is desirable for preventing too strong a current. The wires W from the commercial circuit are attached to the switch.

NOTE 179 D — FIGURE 8 — HINGED FARADAY RING FOR ETHER AND ELECTRON THERAPEUTICS WITH THE SECONDARY SECTIONS IN TWO GROUPS

This is the same transformer shown in Plate 146, Figure 7, but with the secondaries independent instead of in series. Each secondary will give sufficient voltage for the ultra-violet arc or the electron arc or for exciting derma-ray tubes. One secondary is provided with a Tesla, not shown in the photograph, the other with a solenoid S. To provide spark-gaps for the two independent coils, the supports -LJ, LJ 2, LJ 3, LJ 4- are pivoted to allow them to turn from the positions in Plate 146, Figure 7, in a horizontal plane ninety degrees, to the positions shown in Plate 147, Figure 8.


S
LJ1
LJ
LJ3
LJ2

NOTE 179 D — FIGURE 10 — A PORTABLE ELECTRON ARC

The illustration shows one of the forms of electron arc mentioned in earlier papers. The instrument is attached to the hinged Faraday ring illustrated in Plates 146, 147, Figures 7 and 8, by flexible wire cables, which are attached at P and N. The terminal HN is connected with the negative terminal of a high-voltage generator, whose other terminal charges the patient positively. The patient is placed on an insulating platform. The arc formed by the current from the Faraday ring is between the aluminum terminals X. It is rich in ultra-violet light, which, illuminating the face of the disk HN, causes it to send out electrons that bombard the patient's skin when the arc is placed near it, ionizing the tissues. The whole arc is enclosed in an insulating tube T provided with a movable handle H, which allows it to be placed in any position near the patient. The aluminum terminals can be removed and others put in their places, as they are held in tubes BT.

NOTE 179 D — FIGURE 11 — A FORM OF ULTRA-VIOLET ARC

In this arc the negative terminal is a curved plate N, the positive terminal is a blunt hook P, both terminals being made of aluminum. The arc is enclosed in an insulating case T and provided with a handle, to allow the arc to be brought near any part of the patient. The apparatus is connected with the generator by flexible wires attached at PI and NI.

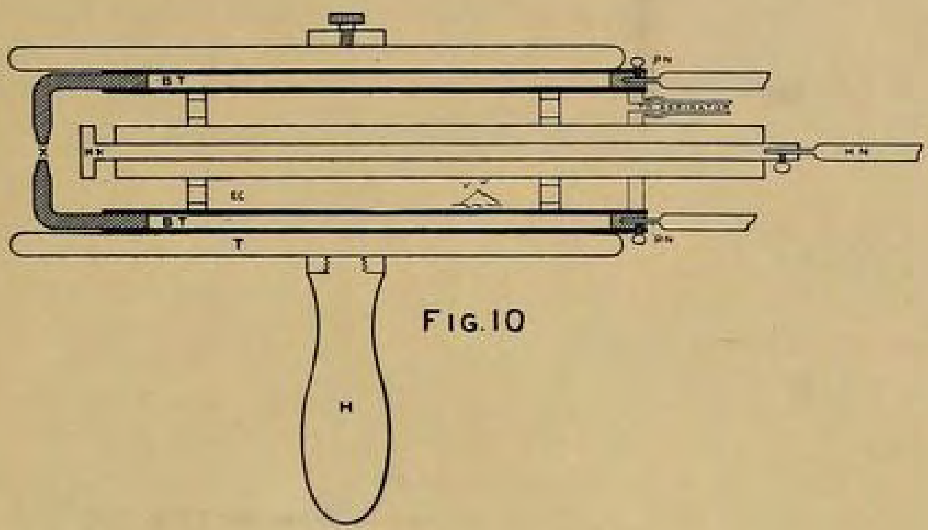


FIG. 10

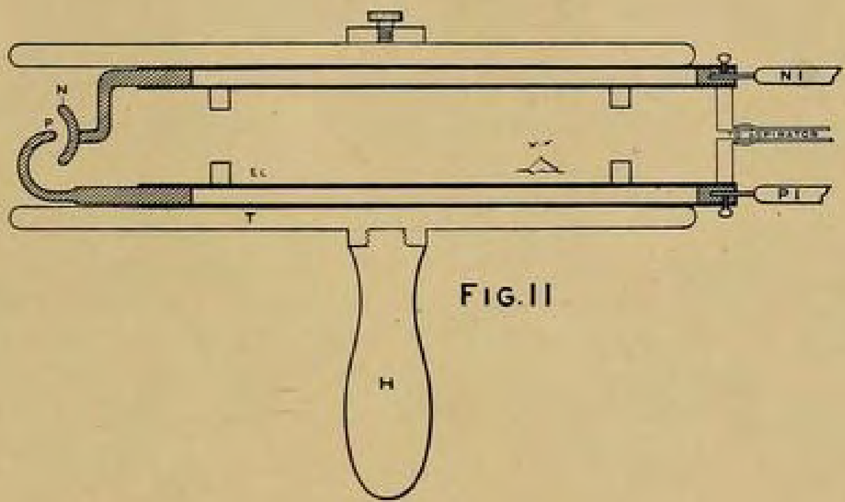
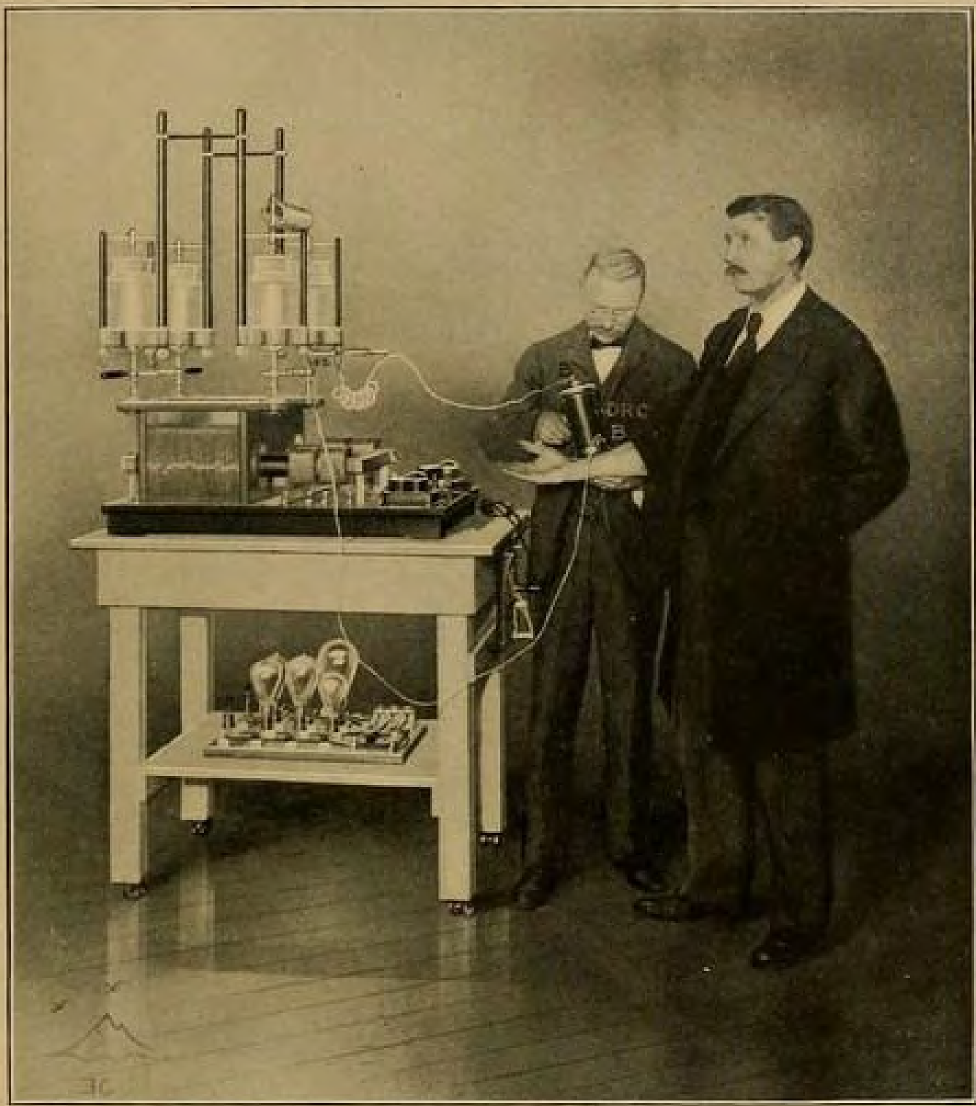


FIG. 11

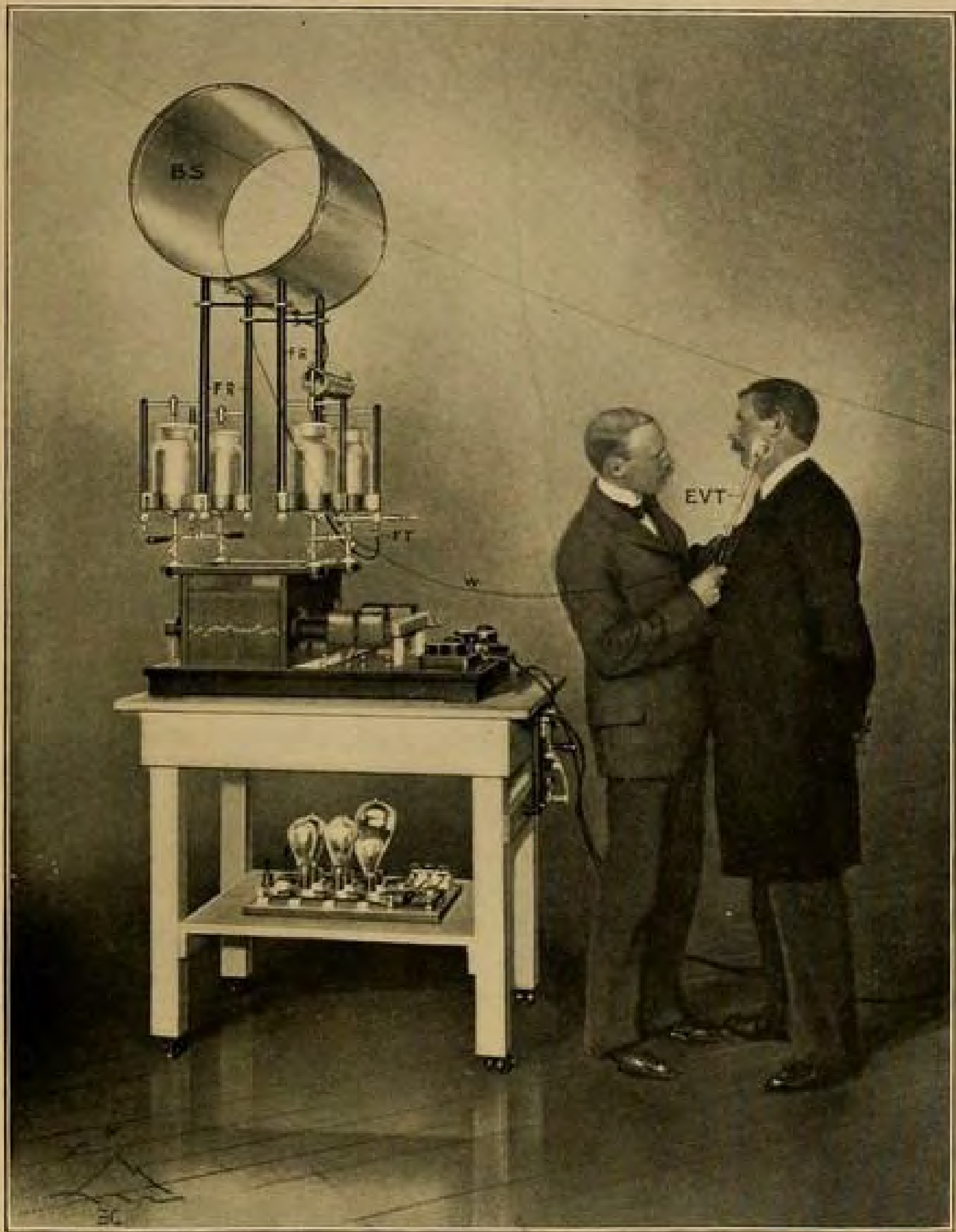
NOTE 179 D — FIGURE 12 — A METHOD OF USING A DERMA-RAY TUBE

The wires leading from the closed Faraday ring are attached to the terminals of the secondary at FT, the other ends being connected with the terminals of the derma-ray tube by means of the binding posts B. The derma-ray tube case DRC is lined with a heavy coating of non-radiable material, and the hand which holds the tube case is enveloped in a non-radiable glove.

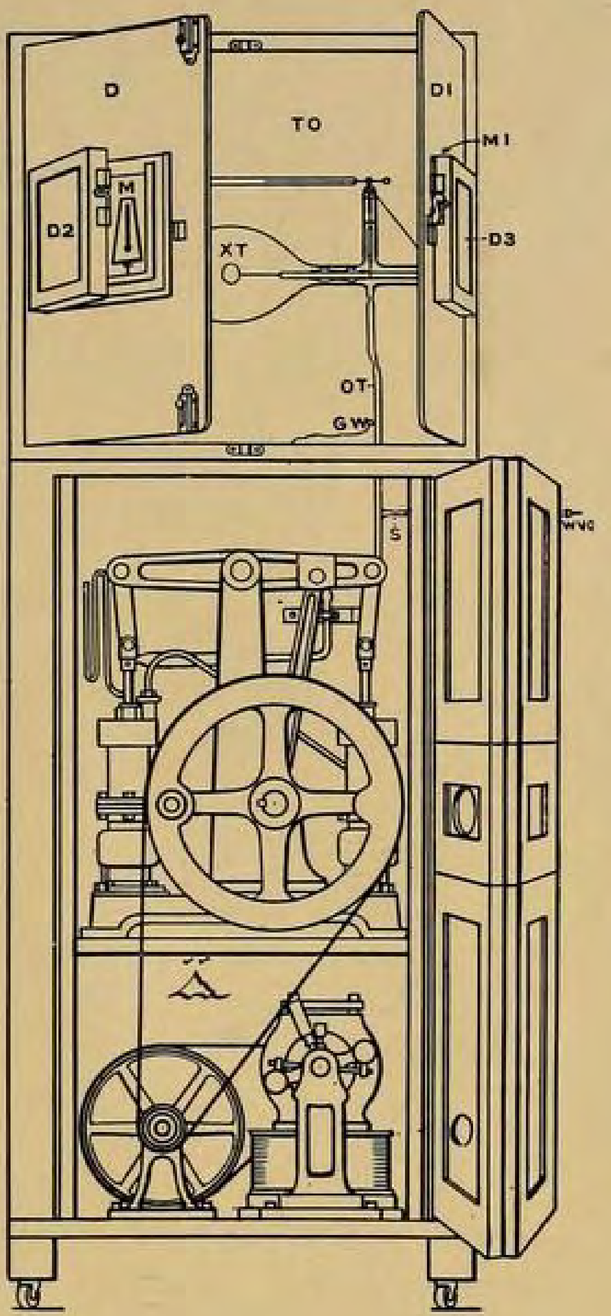


NOTE 179 D—FIGURE 13—A METHOD OF USING A HINGED FARADAY RING FOR EXCITING A VACUUM TUBE ELECTRODE

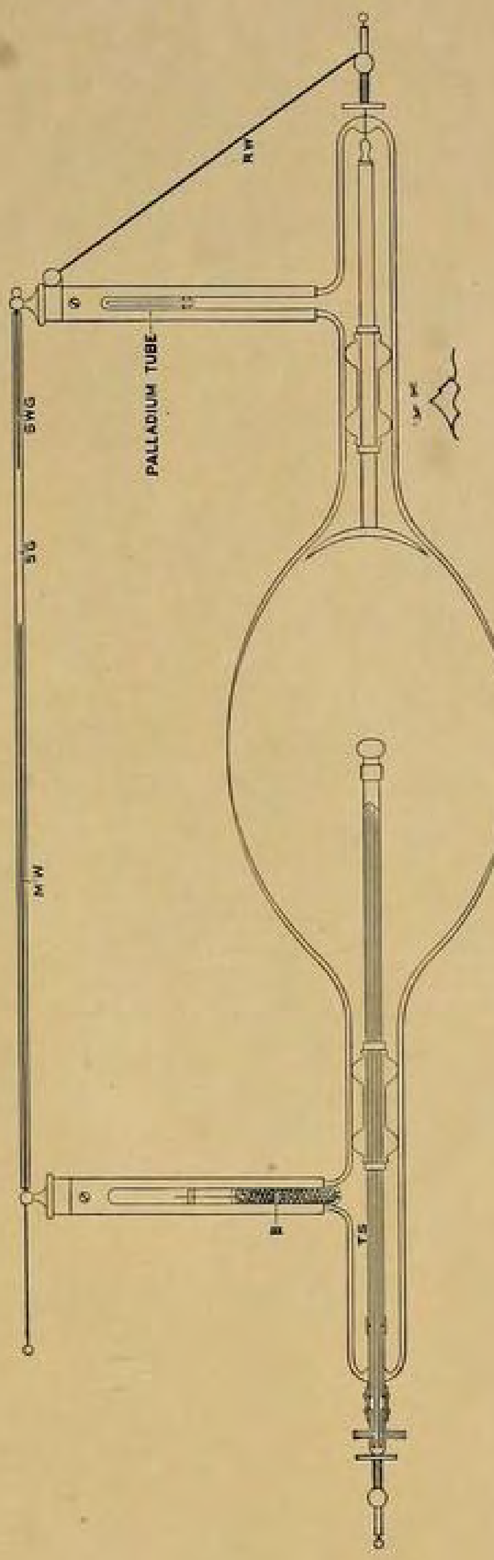
The solenoid BS is supported and insulated by the fibre rods FR, one end being connected with the secondary of the Faraday ring at FT. The other end of the solenoid is attached to a wire W, which is in metallic connection with the electrode vacuum tube EVT. As only one terminal of the secondary of the closed Faraday ring is connected with the vacuum electrode, the current, after leaving the patient, returns to the generator through the ether without a wire to guide it. Under these circumstances, when the room is dark, the generator sometimes presents appearances similar to those shown by the Aurora. The simplest way to regulate the strength of the energy applied to the patient is to vary the current in the primary of the Faraday ring by means of a graduated resistance. The solenoid can be removed from the position shown in the figure and placed on the floor or in any other convenient position. Various sizes of these solenoids should be provided and used after French methods, both terminals being connected with the terminals of the secondary of the Faraday ring, the whole or any part of the patient being enclosed by the solenoid.


BS
EVT

NOTE 179 F — FIGURE 1 — ARRANGEMENT OF A MECHANICAL PUMP FOR EXHAUSTING VACUUM TUBES FOR USE IN MEDICINE


D
D1
TO
M1
M
D2
D3
XT
OT
GW
S

NOTE 179 G—FIGURE 1—AN X-LIGHT TUBE WITH A COOLED TARGET, AN AUTOMATIC REGULATOR, AND A REGENERATOR


RW
PALLADIUM TUBE
SWG
SG
MW
B
TS

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