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ICE CAVES AND THE CAUSES OF SUBTERRANEAN ICE.*

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of Philadelphia, etc.

I. DESCRIPTIVE AND EXPLANATORY.

Terminology.—The term "ice cave" refers to a rock cavern containing ice. It does not refer to a hole or tunnel, cut by the hand of man into a glacier, such as those one sees at Grindelwald or Chamonix. I make this statement, because on mentioning ice caves in conversation I have repeatedly been asked whether I meant those tunnels. The Germans use a term similar to ours, *Eishöhle*, while the French and Swiss use the word *glacière*, the feminine of

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ELECTRICAL SECTION.

Stated Meeting, December 22, 1897.

MR. CLAYTON W. PIKE, President, in the chair.

X-RAYS, APPARATUS AND METHODS.

BY ELMER G. WILLYOUNG AND H. LYMAN SAYEN.

That Professor Roentgen's discovery of the X-ray has initiated many lines of thought, promising to greatly extend our knowledge of physical phenomena as well as to revise many of our previously accepted views, is generally admitted. That the practical results accruing to humanity by virtue of the applications of this discovery in surgical and medical practice, are of even greater promise and value, is equally conceded. The writers have been engaged for a number of months past in developing apparatus and methods for practical work with especial reference to the needs of the physician and surgeon. For conciseness, we have arranged the matter under consideration in a series of subordinate heads, each of which we shall briefly discuss. Your programme committee has thought that some of the results secured might be interesting, in view of the fact that very little literature regarding the technique of X-ray work has thus far been published.

The Coil or Generating Source.—Thus far the only apparatus known which will produce X-rays readily and profusely is the "transformer." By this, however, we do not mean the commercial transformer of every-day use, but its earlier, and for most purposes less efficient form, the "induction coil." Such a transformer gives exceedingly great electromotive forces capable of producing discharge over long air gaps. When the discharge from such a coil is passed through properly exhausted and constructed tubes, we have a very vigorous generation of X-rays.

Two arrangements of the induction coil are advocated. The one is known as the Tesla or "high-frequency" coil, and the other is the direct and old-fashioned use of the simple induction coil, in which the high secondary E.M.F. is delivered direct to the terminals of the tube.

The High-Frequency Coil.—Fig. 1 shows the diagram of the Tesla combination or "high-frequency" coil. It consists, as will be seen, of two induction coils, the induced secondary current of the first being used to charge a Leyden jar. The primary of the second coil is joined, in series with a spark gap, to the two coatings of the Leyden jar. When the Leyden jars are fully charged, they discharge across the air-gap, this discharge being, by well-known laws of electrical circuit flow, an oscillating one of exceedingly high frequency—millions or more oscillations per second. We thus have the primary of the second coil excited by an alternating current of exceedingly great voltage and frequency, so that *its* secondary produces a discharge of still *greater* E.M.F. and of this same high frequency. So great is this final E.M.F., that it is generally necessary to immerse the entire second coil, primary and all, in a tank of oil, since no solid insulation has yet been found capable of standing these great E.M.F.'s without breakdown.

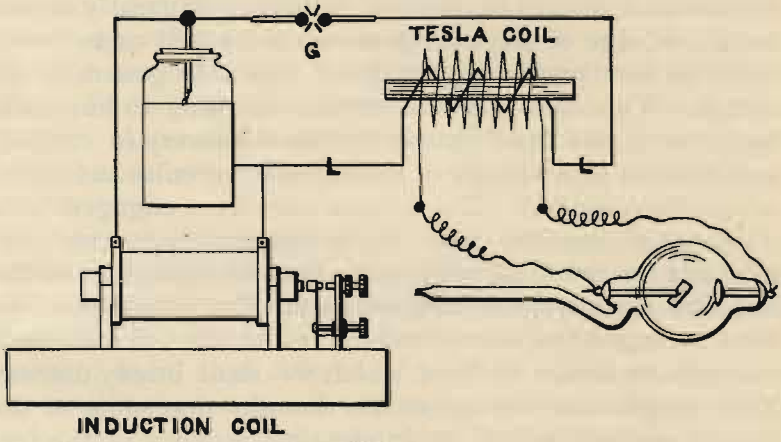

FIG. 1.

To excite the Tesla coil, we may use either an interrupted direct current or an ordinary alternating circuit joined directly to the primary of the first coil. But the final result is, in either case, an alternating, high-potential, high-frequency current. In the tube, therefore, we also have an alternating discharge.

The Induction Coil.—We illustrate, in *Fig. 2*, the scheme of connections, etc., of the simple induction coil. The primary must be excited by an interrupted direct current, which may be secured from primary batteries, storage batteries, or a commercial circuit as may be determined by convenience or inclination. The secondary is joined directly to the tube terminals. The usual means employed for securing the interruptions is some form of vibrating spring device, automatically operated by the core of the coil itself, the magnetic pull of the core attracting a mass of iron which, by its motion, separates two contact points, thus allowing a properly placed spring to draw it back, closing the circuit again, when the cycle is repeated. Such a device is employed in most forms of virbating electric bells and is indicated in the diagram. Around the break is placed a condenser. At break, this condenser charges (thus preventing the extra induced current due to the large self-induction of

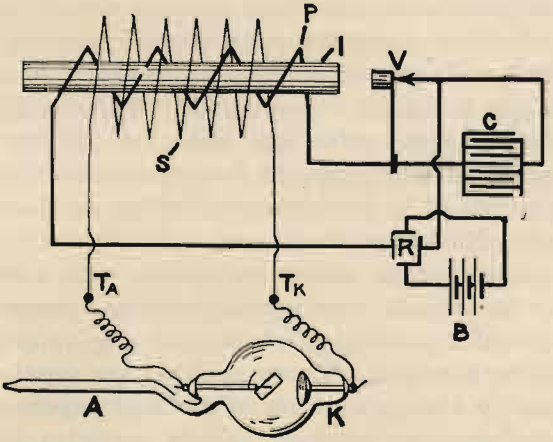

FIG. 2.

the primary), but, being "short-circuited" by the primary, at once discharges about the iron core in a direction *opposite* to the regular "make" current, thus reducing (if correctly proportioned) the magnetic intensity of the iron core to zero. All this takes place so quickly that the practical effect of the action is merely to assist and intensify the dropping off of the core's magnetism—to shove it along—hasten it. Considering the secondary, now, we find that we shall have at *break* an induced discharge of greatly higher E.M.F. than that at *make*, owing to the falling off of the core's magnetism *at* break being greatly sharper than its growth at make. The effect of this is to give secondary discharges in *one direction only* at all times when the spark gap is not *greatly* shorter than the *maximum* obtainable spark gap for that particular condition of running the coil, the *make* induced current at such times being of too small E.M.F. to get across the gap at all. This is always the condition when X-ray tubes are used. A further function of the condenser is to suppress *burning* at the "break" terminals or points of interruption by taking up the energy of the magnetic discharge of the coil.

In the construction of the induction coil, a number of points may be noted. Our secondaries are wound in sections $\frac{1}{8}$-inch thick (according to the plan originally proposed, we believe, by Ritchie). These sections are separated from one another by a large number of discs of paper of a brand especially selected as free from carbon particles, and baked at a temperature a little below charring point for some time immediately before use—this to drive out moisture. These sections are then assembled and immediately immersed in a special insulation composition having a very high melting point, with high specific heat, and some slight viscosity at all temperatures.

Paraffine we absolutely prohibit as being apt to crack and absorb moisture. The melting point of paraffine, also, is so low (not over about 140° F. for the highest), that in warm weather there is serious risk of displacement of some of the sections by their own weight; for the same reason but little energy can be dissipated from the secondary, Another grave danger in the use of paraffine is that due to the acid which it usually contains. This attacks the wire, forming copper sulphate, which dissolves gradually into and throughout the mass of the paraffine, thus effectually destroying its insulating properties.

After cooking for some time in the insulation, to drive out the last traces of moisture, the stack of sections is subjected to a further treatment, by which it is finally cooled *with all air removed.* This we consider a point of the highest importance, as air present anywhere in the secondary becomes electrified and bombards to and fro, gradually softening the insulation and eventually breaking down the coil. (For confirmation of this point, see Tesla, on "High-Frequency Phenomena.") With this plan of construction we have no static leaks of energy, or small direct leaks within the coil itself, and deliver the full energy of discharge at the secondary terminals. We find ourselves able to secure in this way a full inch of spark in all sizes of coils with considerably less than 1 pound of wire, No. 34 B. & S.* We believe that, more than anything else, the large quantities of wire required to produce a given spark length with many of the coils now in use is due to the presence of air, and consequent loss of energy by static bombardment, in the secondary. As regards the insulating composition used by us, we may say that we find its power of resistance to spark discharge to be four or five times that of hard rubber. In the arrangement of our secondary, we separate it from the primary by a heavy hard-rubber tube, and, in addition, by a tube of this composition.

The Adjustable Condenser.—A coil is working to best advantage when there is a certain definite relation between its primary current, secondary spark distance, and condenser capacity. Frequency of break must also be considered. As coils have heretofore been built, however, the condenser value has been fixed once for all and admits of no change, albeit both spark gap and primary current may be so

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* In our latest coils not over three-quarters of a pound to the inch of spark is used.

changed. To remedy this, we have devised a form of switch shown in the diagram, *Fig. 3*, by means of which the condenser capacity may be shifted, at will and instantly, by simply turning the switch. The effect upon the secondary discharge is very marked, both volume and musical note of the spark changing with the position of the switch. We find this idea exceedingly convenient in general experimental work with alternating currents, it being possible with it to alter condenser capacity as quickly and as readily as we may self-induction or resistance. (We have made some experiments in the use of a condenser in parallel *with the primary.* The volume of the secondary discharge seems, in many cases, to be greatly increased.)

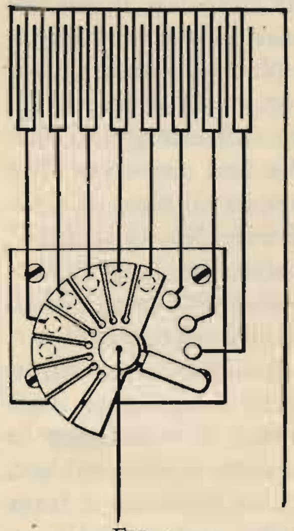
FIG. 3.

In arranging coils to operate from few or many cells of battery it is, of course, merely a matter of winding the primary with coarse or fine wire, the number of ampère turns being kept the same. It is interesting to note, as we have noted experimentally many times, that the larger the primary E.M.F. the smaller must be the condenser capacity employed, and *vice versa.* This is, of course, only to be expected, since capacity and self-induction are inverse functions of each other.

Primary Current.—This may be either from primary batteries, storage batteries, or from a commercial direct-current circuit. Primary batteries have too high resistance to give sufficient current for coils of much size—say 4 inches and over—unless joined in parallel, and then we need a number of such groups to secure the requisite E.M.F. They require constant attention, soon run down, and are expensive to operate. Storage batteries are exceedingly satisfactory, are comparatively inexpensive to operate, and require practically no attention. Charging them is more or less of an annoyance, however, especially where they must be sent out of the building, as they usually must, besides throwing the entire apparatus out of use while the charging is going on, unless one have a reserve set of batteries.

The utilization of a direct commercial circuit, such as the Edison 110-volt (*e. g.*, where such is available), is, in every way, the most convenient and satisfactory. Until Professor Roentgen's discovery, no method of operating large coils upon such a circuit had been developed. Recently, however, several methods have been brought out, notably that of the "air break," with air blast to blow out the spark, as used by Dr. Wm. J. Morton, Dr. M. I. Pupin, and others. In *Fig. 4* we show a form of apparatus devised by us to accomplish this purpose. A Lundell $\frac{1}{12}$ horse-power motor is supported upon a base with its shaft vertical. A casting, attached to the motor, supports above the latter a copper can made up of two concentric cylinders joined by a ring below, so that the shaft passes up through the inner cylinder and thus avoids the necessity of a stuffing-box. From the shaft is

FIG. 4.

hung, well within the can, a heavy brass wheel, having stretches of insulating slate let into its periphery. A hard-rubber lid fits over the top of the can. Mounted upon this lid are two brushes, one bearing against the wheel periphery and one against the shaft; suitable springs and screws allow the brush tension to be varied. From the commercial circuit leads are brought to these two brushes, the current being first passed through the primary of the coil and a rheostat in series. Before the lid is put in place the can is filled with distilled water; ordinary hydrant water will answer, although its usual impurity soon causes the water to become dirty, besides allowing a certain amount of electrolysis during use. With distilled water the break may be run for a number of hours without change of the water and very little heating takes place. The real function of the water is not so much to drown the spark as to prevent heating, although it does, of course, also assist in quenching the spark. But a condenser is the real spark extinguisher, and this we connect around the break just as we would around an ordinary vibrating break.

The advantages of this break over all forms of vibrating break thus far known, and over other forms of rotary break, are:

(*a*) *Convenience.*—Mere throwing of a switch being all that is required to start and stop the apparatus.

(*b*) *Noiselessness.*—Only the drowsy hum of the motor being heard.

(*c*) *Reliability.*—No chance of sticking, as with vibrating breaks.

(*d*) *Variable Rate of Break.*—Secured by adjusting rheostat in base of motor.*

(*e*) *Smooth, Unvarying Fluoroscopic Images* by reason of the large number of breaks per unit of time.

Another great advantage of the rotary break is the almost perfect control which it gives over the spark length.

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* We have found that the vacuum of a tube often gets into such a condition as to make the tube absolutely unworkable at a given frequency of break, whereas, a slight *change* of frequency immediately restores the X-radiation.

This is on account of the independence of the coil and the break, thus permitting the breaking of any desired value of current without the slightest change in either frequency or character of break. With the usual vibrating break, operated by the core of the coil, the character and frequency of break is necessarily a function of the value of current, being broken and changed with it. It is impossible, with a large coil, *e. g.*, to get uniform and continuous secondary discharges of a length very small compared with the maximum capacity of the coil, since to such short sparks would correspond a magnetization of the core insufficient to operate the vibrator at all. But with the rotary break we may make the current as small as we please, without in the slightest degree interfering with the frequency and precision of the break.

Two milled heads at top of can permit its lid (carrying brushes) to be withdrawn. A similar head at top of shaft loosens break-wheel, and two heads at bottom of can allow it to be lifted away for cleaning and renewal and replenishing of water.

We use three makes and three breaks per revolution and find best results at from 1,200 to 1,400 revolutions per minute (equal to 3,600 to 4,800 interruptions). We may secure as many as 2,000 revolutions (6,000 interruptions) per minute, by cutting out the motor regulator.

In operation, the brush bearing upon break-wheel should be *positive*, so as to prevent any electrolysis of the break-wheel. We have often broken between 15 and 20 ampères through this wheel for a considerable length of time without any overheating or excessive wear of the wheel. Should the wheel wear in time to an undesirable degree it may be removed and turned down. Provision is also made for replacing the brushes when desired.

General Considerations Regarding Break Frequency.—The question as to whether there is a certain best frequency of break for a given coil or tube or both, has puzzled not a few. Very little has been experimentally determined regarding this point. It is certain, however, that, with a given coil or tube, shortness of exposure is *not* exactly inversely as the number of breaks. Indeed, it is often far from being so. Some of the best X-ray pictures that have been taken have been by the use of the old "hammer" break of Ritchie, and 4 or 5 clicks of the break have sufficed. Using the same tube and coil, but a rapidly vibrating or rotary break, required 40 or 50 breaks to accomplish the same results. It would appear, hence, that the energy of X-ray radiation *per break* is a function of the number of breaks per unit of time.

We are inclined to believe that this is a matter purely of the "time constant" of the coil. The iron of the core requires a certain time to magnetize and demagnetize. With the breaks few, ample time is given for this process, but when the breaks become rapid this is no longer possible, so that the secondary E.M.F. falls—this may easily be verified by observing the maximum spark length of any coil—with single breaks, few and far between, we get much longer spark maxima than if the breaks are frequent. The thickness of the sparks is also greatly increased. If, however, we increase the *primary* E.M.F. for the more rapid break we may bring up the secondary spark length to the value given by the single breaks. We should thus be able to shorten the exposure as much as we please, by merely increasing the rate of break and the primary E.M.F. at the same time; but here we are limited by the *tube* which cannot *dissipate* more than a certain definite amount of energy in a given time and will break down if overdriven. We see, therefore, that whether we use slow breaks or fast breaks, the actual time of exposure remains practically the same, the few breaks requiring to be distributed over the same *time* as the much larger number of rapid breaks. All this, of course, applies to the photographic plate. For fluoroscopy we require rapid breaks in order to escape the otherwise distressing flickering.

In the above connection, particular attention is directed to one point—the rate of break *must not be too great*. If it is, the iron no longer has time to magnetize and demagnetize. The result is an *alternating* secondary discharge instead of the *direct* discharge desired, and this means blackening of the tube, *rapid fluctuations of the vacuum, and general deterioration of the tube. We doubt whether, with any coil of size suitable for X-ray work, a rate of break greater than 5,000 per minute should ever be employed.*

Tesla Coil or Induction Coil—Which?—Having carefully examined the results, apparatus and methods of others all over the country, devotees some of the "high-frequency" coil, some of the induction coil, and having made many and careful experiments with both forms of apparatus ourselves, we favor the induction coil. Our reasons for this preference are briefly stated:

(*a*) *Simplicity.*—One coil instead of two.

(*b*) *Ease of Manipulation.*—There being more than double the number of factors to attend to in the Tesla coil than in the induction coil.

(*c*) *Cleanliness.*—The "high-frequency" coil requires an oil bath, which must be renewed from time to time to avoid gumming. It is difficult, also, to find an oil which will not, eventually, act upon the insulation of the wire by virtue of the acid or other impurities which the former may contain.

(*d*) *Sharp Definition.*—The "high-frequency" coil produces an alternating discharge -thus with the double focus tube giving us *two* sources of X-radiation and consequent blurring of the image. If a single focus tube be used, the discharge in one direction is either lost or tears off particles of the platinum reflector, thus blackening the tube and soon destroying its effectiveness.

(*e*) *Noiselessness.*—This, from the surgeon's and physician's standpoint, is, perhaps, the most important consideraation. With tube in action, the induction coil is practically noiseless, save for the low hum of motor or vibrator. Improperly designed vibrators often rattle and rasp in a very irritating manner. In the "high-frequency" coil, however, the disruptive discharge over the air gap is the vital cause of its action. It is much more violent than a discharge of corresponding length from the induction coil, being of a rattling, cracking character. That such noise cannot but have a most unpleasant effect upon the patient who comes into the operating room in a condition of more or less nervous collapse to begin with is obvious.

(*f*) *Strain on Tube.*—It has been argued by advocates of the "high-frequency" coil that it is much less hard upon the tubes. Our own observation has been just the reverse of this, and has satisfied us that the wear and tear is very much less with the induction coil.

(*g*) *Results.*—Although we have diligently examined, we have yet to see results obtained by any form of apparatus superior to those made in Philadelphia by Dr. Goodspeed, of the University of Pennsylvania; Dr. Stern, of the Polyclinic Hospital; ourselves, and many others who might be mentioned, and this either as regards detail, penetration or quickness of exposure. Indeed, we may say that we have never seen results obtained with the Tesla coil that are equal in any of the above respects to the results just referred to.

The Tube.—Many forms of tubes have been suggested. With practically no exception, all tubes now in use employ as cathode a concave aluminum disc, whose center of curvature is at the center of a small platinum plate ($\frac{3}{8}$ to $\frac{3}{4}$ square inch in area) the plane of the plate being inclined to the normal from center of the concave cathode. This platinum plate is sometimes made the anode—sometimes the anode is a separate plate or wire elsewhere in the tube. This form of tube is known as the "focus" tube, the cathode rays being focussed upon the platinum plate, which then becomes the active source of X-rays. In the double-focus tube we have two concave cathodes at opposite ends of the tube, the platinum wire reflector being in the form of a wedge with a side presented to each of the concave cathodes.

In the use of the tube everything depends upon the vacuum, X-rays seeming to be of a heterogeneous character, just as are light rays, their quality varying with the degree of vacuum. The higher the vacuum the more penetrating power the tube has, hence it is well to select tubes and use different tubes for different purposes. A tube of extremely high exhaustion is best for working through the body, but with forearm, hands, feet, etc., such a tube has too great penetration, the bones appearing almost equally transparent with the flesh.

The chief difficulty with most tubes is the change of vacuum which takes place in use. This is thought to be due to the occlusion of the residual gas upon the inner surface of the glass—resulting in an *increased* vacuum; advocates of the bombardment theory believe it to mean an actual driving of the gas out through the body of the tube. It may be partially restored by heating the tube by use of a spirit lamp or Bunsen flame. This must be very carefully done, however, to avoid cracking the tube. When the platinum reflector is used simply as an anti-cathode, and the anode is aluminum, a simple reversal of the discharge will prove fairly successful. Some makers have adopted the scheme, practised now for many years, of blowing a small side pocket upon the tube, into which is placed phosphoric anhydride or some other chemical substance or composition absorbing moisture. When heated, this substance gives off vapor to make up for the loss; it is difficult, however, to drive off just the right amount of vapor in this way, and the vacuum is liable to be made too low, in which case flesh and bone are about equally opaque. So rapid is this change of vacuum with the majority of tubes, that in most cases involv-

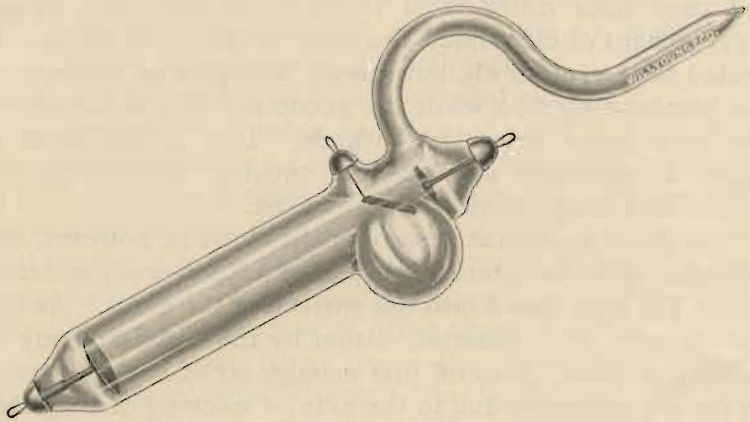

FIG. 5.

ing over a few minutes' exposure or running of the tube one of the above methods becomes necessary. In any case, eventual, almost complete, exhaustion seems to be the rule, and the tube must then be returned to the makers and re-exhausted.

"Blackening" is another cause of decreased efficiency in the tube. It is due to deposition of platinum upon the inner surface of the tube.

The "Bowdoin" tube, shown in *Fig. 5*, was devised after a considerable amount of experimental work, by Profs. Robinson and Hutchins, of Bowdoin College. In general design it does not differ essentially from many other forms of focus tube upon the market. The two respects in which the tube does differ from other tubes are, first, in the arrangement of electrodes, the reflector plate not being connected to the coil at all, but merely acting as an obstacle to the bombarding rays, while the anode is a disc at the end of the tube away from the cathode. This arrangement is found to perfectly and entirely prevent blackening, no matter how long the tube may be used.

The most important feature of this tube is, however, the presence upon its interior surface of a fluorescent material which has been fused into the surface of the glass.* As the tube is used, this material, either by the bombardment or heating, or both, gives off just enough air or vapor to make up for the occlusion due to the natural working of the tube. The vacuum, therefore, tends to remain always constant. Although it seems almost absurd that one could put in just enough of this material to make up for the gas otherwise lost, yet it is a fact that these tubes remain practically unchanged in vacuum for a very long period.

In use the tube requires no "nursing" whatever. It should always have, to start with, a parallel spark gap, which should be quite small, say 1 inch or 1½ inch, and either the primary current or the vibrator tension adjusted so as to

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* The fluorescent quality is not supposed to have any effect upon the result; it merely *happens* that the particular substance found most effective is fluorescent.

produce only a very small secondary discharge. The energy of this secondary discharge may then be immediately increased until the reflector plate shows a dull red spot of about half the size of the nail of the little finger. The tube is now in its most efficient condition, and, with a well constructed and smooth working break, may be run for an hour or two without the slightest attention. The "getting ready," as above described, takes considerably less time than the time it has taken us to describe it. Indeed, in our own work, we do not trouble to make this preliminary adjustment at all, as we make it once for all when we first begin to work with a tube and do not afterward disturb it, merely closing down the switch when starting work.

Life of Tubes.—The life of tubes in general is limited—

- (*a*) By time required for the vacuum to become too great, hence requiring re-exhaustion.
- (*b*) By ability to stand the electrical strains.

(*a*) Applies to all tubes, so far as we know, save the Bowdoin tubes—probably six or eight hours' continuous working, or the equivalent suffices to incapacitate the average tube. We think that even with the Bowdoin tube there is an evident tendency to eventual very high vacuum, but the time required is quite large, relatively, say ten to fifteen times that operative in the case of other types of tubes.

(*b*) All well-made tubes (from the glass-blower's standpoint) are about equally liable to this limitation. It is probable that these strains are cumulative in their effects upon the tube, the latter gradually weakening until eventually breakdown takes place with secondary discharges much less than would have been originally required for breakdown.

The Stand.—The stand, shown in *Fig. 6*, has been devised by us for applied X-ray work. With it the tube may be placed in any position within a cylinder 6 feet high and 6 feet in diameter, thus making it possible to get under or over a patient, no matter what the latter's position. Four rods (two are not shown in the figure) of vulcanized fibre clamp to the stand in any position and carry the lead wires of the tube, thus keeping them away from one another and from the metal of the stand. They carry little spring clips at their extremities, by which the wires are caught without tying or bending.* The whole stand is of bicycle tubing and very rigid.

The Subject.—The patient should, of course, be placed in as easy a position as possible. For body pictures, hip and knee joints, etc., a recumbent position may be assumed. The plate should lie beneath and upon a stiff board backing to avoid risk of breakage. Work upon the shoulder, neck, head, etc., may be done with the patient straddling a straight-backed chair, facing the back, and leaning the body against the back for support.† The plate may be bound fast to the body by bandages.

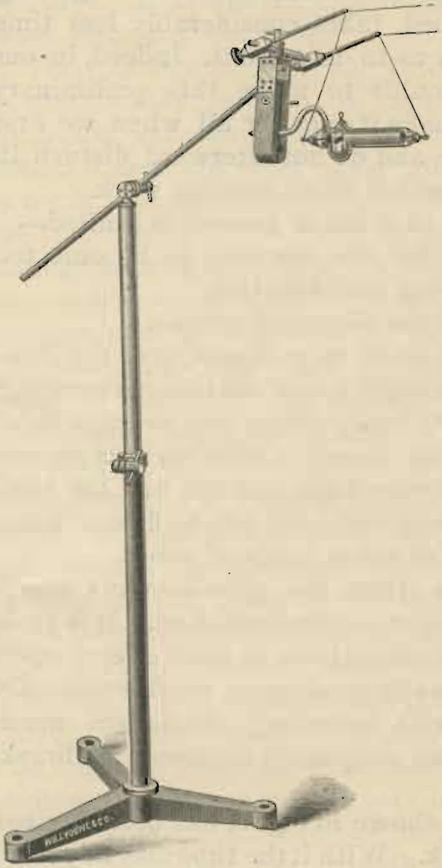

FIG. 6.

Laws for Exposure.—Since the X-rays proceed in straight lines from (approximately) a point source, the intensity of their action varies inversely as the square of the distance from the source. Hence, the *time of exposure* should vary directly as the *thickness* of the intervening substance and the square of the distance from the plate. To

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* This is also a great convenience in changing the position of the stand after everything is connected up—as must often be done. The wires simply slip out of the clips, thus relieving the tube of all strain.

† For this suggestion we are indebted to the practice of Dr. Max Stern, of the Philadelphia Polyclinic.

apply these principles in practice, take a trial picture of the hand at 5 inches distance, this being amply sufficient for good definition with such small bones. Say one minute is required for a good result. Then to take a hip joint, we estimate the thickness of the latter to be, say, ten times that of the hand. We must, therefore, expose ten minutes on account of thickness alone. But, owing to the greater distance of bones from plate, the tube must be removed much further to get definition. At least 15 inches from the dry plate should be given—this is three times the distance used for the hand from which the *times* require to be as the squares of these figures, or as one is to nine. The *total* exposure must, therefore, be ninety minutes. This method gives something to go upon. After a little experience, perhaps the most convenient thing to do is to arrange a little table, based upon previous results, and showing times and distances required for well-defined results for distinctive parts of the body.

Short Exposures.—We have obtained and do regularly obtain without difficulty well-defined pictures, showing complete detail of the osseous structure involved in times and with distances from dry-plate to reflector, as below:

Hand and wrist	5 to 10 seconds,	at 5 inches.
Forearm	10 " 15 "	" 5 "
Arm above elbow	½ " 1 minute,	" 7 "
Shoulder	10 " 15 minutes,	" 10 "
Thorax	15 " 30 "	" 10 "
Hip joint	30 " 45 "	" 12 to 15 inches.
Stones in kidneys	30 " 45 "	" 12 " 15 "
Glass, iron, lead, etc., in any part of trunk	30 minutes on an average,	at 12 to 15 inches.

We have very carefully investigated every claim to quicker exposures than these, often by a personal visit, sometimes by correspondence with personal friends whose reliability was undoubted. We have been unable to learn of any results equally good having been obtained in shorter times by any one at any place with any form of apparatus, and we do not believe any such have been obtained.

Manipulation—Development of the Plate.—Suitable and well-constructed apparatus is not the only essential to good results. A great deal depends upon the operator, and comparatively trivial differences in procedure make all the difference between success and failure. We describe here the method which we follow and which allows us to count with certainty upon securing at least nine successful plates for every ten exposures.

General Adjustment.—First see that the coil is working smoothly and so as to give a uniform discharge in the primary. The secondary spark points should be separated by the distance given by the makers as proper for the tube. The coil must then be adjusted either by changing the E.M.F. at the primary or by variation of the vibrator adjusting springs, so as just *not* to spark over this air gap. The tube should then be joined in parallel with this secondary spark gap. The coil may then be started up, using the fluoroscope to show whether direction of discharge is right. If not, the primary current should be reversed. If X-rays are not now profuse, the secondary discharge points should be further separated and the vibrator springs tightened so as to produce correspondingly greater discharge. Continue this until either X-rays are secured as desired, or the tube becomes too hot, or possibly bluish or pink in color. Blue denotes too low a vacuum to expect X-rays, but often a gentle running of the tube for ten or fifteen minutes, while in this condition, will raise the vacuum to a suitable value. Pink denotes a *very* low vacuum and usually means, in a tube which has ever *been* right, a puncture or leak; *such a tube* can only be made good by re-exhaustion and repair. With many tubes a vivid green fluorescence is the sign of the X-ray vacuum. With the Bowdoin tubes, as also with many others, the most efficient condition is with the platinum reflector plate at cherry-red heat over an area of one-half or two-thirds that of the little finger nail.

Sometimes the vacuum will be too high for the production of X-rays with *any* length of secondary discharge. It may be reduced by gentle warming of the tube by a spirit-lamp flame. Sometimes reversal of the current in the tube will answer, but this is apt to blacken.

Sticking of the Vibrator must be guarded against—*it is often fatal to the tube.* This is because of the much larger current through the primary when such sticking occurs. Upon release, therefore, a secondary discharge much above normal is produced, and this the parallel spark gap is unable to carry off. The tube, therefore, receives much more energy than it should, and may break down even though the parallel spark gap be as advised by the manufacturers.

(*b*) *The Plate and Its Development.*—We have used at one time and another a number of different makes of plates with very fair success. For some time past we have confined ourselves to the Carbutt X-ray plates, and though we are not prepared to say that they are the best plates to use, the results are so uniformly good as to make it seem advisable to us to try other plates not radically different in principle.

For developer, we use the Carbutt "J. C. tabloids"—3 J and 3 C, to 5 ounces of water—*add about 2 drachms of restrainer* (the usual 10 per cent. solution). Heating this developer to about 65° or 70° F. just before using, we also find to have beneficial results.

From 15 to 20 minutes will be required for development. The image will come up very slowly and not very sharply. Not much detail will be visible by holding up to the light. Continue development until the general main outlines have appeared and faded away to a general blackness upon the glass side. Then rinse and hypo.

The fixing generally requires from a half hour to two or three hours. This long time is probably *partly* due to the unusual thickness of the Carbutt X-ray films, but probably even more to some chemical condition set up by the unusually large quantities of restrainer used. Mr. Carbutt advises *3* J and *3* C tabloids to *6* ounces of water to *20-30 drops restrainer.* Our experience is that a plate so developed *always requires intensification*; a tedious nuisance, which can never give as good results as a normally exposed and developed plate.

Fluoroscopy.—As a really efficient aid to investigation or to surgical practice, the fluoroscope has thus far proved rather disappointing. In case of very definite fractures of arm or of leg below the knee, as also in certain cases of gunshot wound in these same parts, the fluoroscope will afford definite knowledge. But in all troubles affecting the trunk, upper leg, etc., the indications are too blurred and vague to be relied upon. A good part of this indefiniteness is doubtless due to the *phosphorescent* quality of the screen, which causes images to be retained for an appreciable time after they are formed, so that unsteady holding produces superposed images, while we also have a molecular disturbance extending in every direction in the plane of the screen, producing visibility where no direct X-ray disturbance has been produced. Part of the difficulty is also probably due to the natural inefficiency of the screen, which, as employed in this country, is merely of tungstate of calcium. The platinum salts, especially the platinum barium cyanide, is much superior to the tungstate of calcium, but considerably more expensive; it is generally used abroad. The results obtained with it are much more brilliant than those gotten with the tungstate. It is probable that there are other salts or combinations of salts still more powerful than the platinum.

In using the fluoroscope the room should be made as dark as possible, as the eye thus becomes many times as sensitive. Good tubes are often condemned on account of lack of appreciation of this fact and because they do not reveal much detail when used in a lighted room. We have often seen tubes which would not reveal even the bones of the hand in a lighted room, which, after keeping the eyes in the dark for five or ten minutes, would give very clear fluoroscopic images of the ribs, spinal vertebræ, heart, etc.

It does not follow at all that tubes giving poor fluoroscopic results will also give poor photographic results, or *vice versa*, although usually there is a certain correspondence between the two ideas.

General Considerations.—Speaking mainly from the surgeon's point of view, only experience can insure good results with X-ray apparatus. No matter how simple the apparatus may be, how many safeguards be embodied in it, how explicit and full the directions, there are still a vast number of little points which no book can teach, no tongue tell, and which must be learned. To do the best work, one must be something of a physicist, a photographer, surgeon and doctor, all in one. If he *is* not he must *learn* to be by occasionally injuring his apparatus, and certainly by breaking many tubes.

Particularly must the practitioner be cautioned against expecting too much. Many come to their fluoroscope or X-ray photograph for the first time, expecting to see the whole structure of the body exposed before them as if upon a painted wall chart. This is never the case. Except in the case of the hand, foot or forearm, but little could ever be made out in the fluoroscope were one unaware of what *should* be seen. The photographic plate results are usually better and more definite, but even here interpretation is often difficult.

Stated Meeting, January 26, 1897.

AN IMPROVED AUTOMATIC INTERRUPTER FOR INDUCTION COILS.

By H. Lyman Sayen and Elmer G. Willyoung.

For a number of months we have been engaged in the systematic development of induction coils, with particular reference to their use in practical X-ray work. The requirements which must be met in such apparatus are vastly more severe than those which have belonged to induction coils as heretofore made. Up to the time of Prof. Roentgen's discovery, coils have been used only for occasional demonstration in academic class-rooms and occasionally for certain scientific investigations, as, for example, in spectroscopic analysis. Under these conditions a great many inconveniences could be put up with without difficulty. The strains put upon the coils lasted but for a short time, and occasional sticking of the vibrator or excessive burning of the contact points during the brief period of the coil's action were permissible. Now, when coils must be run for an hour or two continuously, and, further, must be run by a class of users whose training in physics and the use of physical apparatus is exceedingly meagre, it is obvious that all these small details must be greatly perfected. A number of the improvements which we have made, we have presented to you in previous papers. We wish to-night to bring before you a new form of automatic interrupter which possesses, in our opinion, many advantages over other forms of interrupters, and which in some respects, we believe, is unique.

In *Fig. 1* we illustrate in diagram the well-known Apps vibrator, which is, perhaps, as largely used all over the world as any form of vibrator thus far devised, and which in its construction and operation is typical of the majority of known forms of vibrators. In action, the hammer-head (*A*) is attracted by the iron core, thus breaking the contacts (*B* and *C*). The head (*A*) immediately flies back by virtue of the resiliency of the spring (*D*), thus again closing the contacts (*B* and *C*) and allowing the process to be repeated. The tension of the spring may be varied by means of the lower adjusting screw (*F*), which, however, it will be observed, applies the force in a manner mechanically undesirable. But the chief defect in this type of vibrator is the defective principle involved. We see that the circuit is closed by the coming together of the points (*B* and *C*). In breaking the circuit, we require, theoretically, great suddenness, but this we are obviously unable to get since the

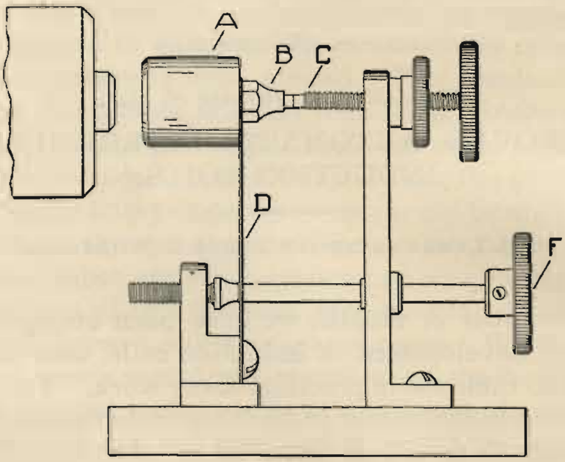

FIG. 1.

hammer-head is at rest and requires a very appreciable time to attain any great velocity of movement, while the current is reduced nearly to its zero value by the first infinitesimal movement of the contact point, thus correspondingly reducing the magnetic pull. Furthermore, the violent blow given to the one contact point by the other throws the spring into a condition of forced vibration, which entails consequent irregular breaking and corresponding irregular discharge in the secondary.

Turning now to *Fig. 2*, we see that the plan of interrupter is entirely different from that just described. The spring (*G*) is supported at its lower extremity, just as with the Apps vibrator, but is otherwise entirely free. Surrounding the spring, near the hammer-head, is a yoke (*H*), rigidly attached to a stiff casting (*I*), which is itself pivoted below. This casting carries the front contact point (J). The back contact point (*K*) is controlled by a pair of set-screws (*L*), while a lower adjusting screw (*M*) controls the tension of a helical spring (*N*), itself attached to the casting (*I*). The spring (*G*) is very stiff and when vertical stands entirely free of the yoke (*N*). In action the hammer-head is attracted by the core, but, quite otherwise than in the

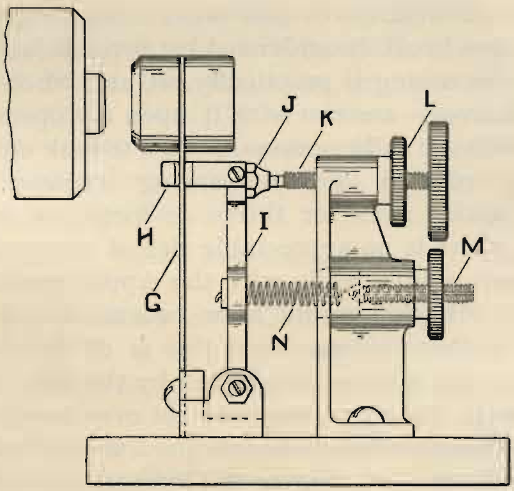

FIG. 2.

Apps interrupter, is able to move a considerable distance and attain a very high velocity of motion before striking the yoke, and thus breaking the circuit. The magnetic pull on the hammer-head being thus released, the hammer-head flies back, partly by virtue of its own spring (*G*) and partly on account of the pull of the spring (*N*). The contact points coming together close the circuit once more, and the core's magnetism immediately begins again to act upon the hammer-head, the motion of which, however, it cannot instantly stop, and the head swings on, being gradually brought to rest and its motion reversed again, striking the yoke while moving at high speed.

That the suddenness of this break is vastly greater than with the Apps break is evidenced by several facts. In the first place, the arcing is practically nil, and when coils—say 8- to 12-inch even—are run with it upon a proper electromotive force, it is actually necessary often to look closely at the vibrator in order to *see* any sparking *whatever*. Further, after continuous runs for thirty or forty-five minutes, or even more, there is no appreciable rise of temperature even at the contact points, while with the Apps break the entire mass of the vibrator would have become too hot for the touch. A further evidence (and this is of decided importance) is that the same coil operated by the new vibrator, as compared with the Apps, requires not over one-half the current to produce results equally as good, if not better.*

Another feature of this new vibrator, gained for it by the characteristics which we have just brought out, is that it is capable of direct use upon a commercial circuit of 110 volts, requiring only a rheostat in series with primary to hold the current down to a suitable value. The sparking on such a circuit is greater than with battery, though not so great as with the majority of the vibrators now used with various coils when run by battery.

It is clear that with this form of vibrator we also get

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* In an actual test of a 12-inch coil, while giving 10-inch sparks, a 2-inch piece of No. 32 copper (B. & S.) wire was inserted into the primary circuit and grasped between the thumb and forefinger. The heating was not too great to be easily endurable.

rather longer makes than with the Apps vibrator. To change the speed of the vibrator we have only to screw a vertical rod into the hammer-head and upon it place an adjustable bob.

Workers with induction coils have probably noticed the irregular secondary discharge often produced where the vibrator castings were weak or insecurely fastened to the base. This is due to the parts getting in to a condition of forced and independent vibration, partly due to the shocks sustained by the contact points, and partly to the vibrations produced in the coil and reinforced by the resonance of its base. In our vibrator we have successfully overcome this difficulty by making our castings very stiff and mounting the parts upon a hard rubber base, which base we carefully surround by heavy felt, and then by a brass box, which clamps the whole firmly to the base. In this way the vibrator is not mechanically connected to the rest of the apparatus, and any vibrations transmitted to it are instantly damped out by the felt.

NOTES AND COMMENTS.*

DOMESTIC STATISTICS OF THE ALUMINUM MANUFACTURE IN 1896.

From the annual reviews of the various metal industries for 1896, published by the *Engineering and Mining Journal*, the following data relating to aluminum industry in the United States will interest many of the readers of the *Journal*:

The production of aluminum in the United States during the year 1896 was 1,300,000 pounds (650 short tons), as against 900,000 pounds (450 short tons) in 1895, showing a gain of 400,000 pounds (200 short tons), or 44 per cent. As has been the case for several years past, the entire domestic output came from a single producer, the Pittsburgh Reduction Company, whose plant at Niagara Falls has been enlarged, and has been working at nearly full capacity. The advantages of this location are very great for comparatively cheap electric power, and the company, for this and other reasons, has been in complete control of the domestic market. Bauxite is chiefly used as raw material, the company controlling the Georgia Bauxite Company, which in 1895 leased for a term of years the bauxite deposits on the Barnsley estate,

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* From the Secretary's monthly reports.