DEPARTMENT OF DENTAL AND ORAL RADIOGRAPHY

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X-RAY MACHINES

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IT is no longer necessary to advocate the use of the x-ray in any of the various branches of dentistry, as the profession has at last awakened to the fact that this agent is not to be regarded otherwise than as a necessity. As a result of this conclusion, most up-to-date practitioners are contemplating the installation of x-ray apparatus as a regular part of their office equipment. While many are actually taking steps in this direction, the majority are putting off the actual purchase of equipment, as they are more or less at sea concerning the apparatus which is best adapted to their needs. This is due for the most part to the fact that the dentist of today is offered such a wide choice in the way of equipment, and also to the fact that some representatives of manufacturers of x-ray apparatus are so extravagant in their claims, that the prospective purchaser hardly knows what to believe and what not to believe.

Of course, the first requisite of the dental x-ray laboratory which the dentist must consider is the so-called x-ray machine. Inasmuch as this requisite is such an important factor, the author has deemed it expedient to discuss the subject with the hope that by properly classifying them, he may make it possible for his readers to more intelligently cope with the problem of the selection of this particular piece of apparatus.

The object of the so-called x-ray machine is to produce a high potential electric current which can be passed through the x-ray tube and thereby produce the x-rays. The ordinary lighting current of 110 volts is inadequate for this purpose, as it is of far too low potential (voltage) to pass through the tube, as the vacuum offers a resistance which to the ordinary current amounts to an absolute nonconductor. We are obliged, therefore, to make use of some electrical means whereby the ordinary current may be "stepped up" to a high voltage, a voltage we will say of from 75,000 to 150,000 volts.

To do this we must make use of one of the electrical machine which can generate such a current by utilizing the principle of electro magnetic induction.

Fig. 1.—Diagrammatic illustration of the essential parts of an induction coil. *A* and *A'* are the terminals of the "primary" coil. *B* represents the windings of the "primary" about the magnetic core *C*. The insulating medium between the "primary" and "secondary" is shown at *E*. The windings of the "secondary" coil are designated by *F*, and the "secondary" terminals by *B* and *B'*.

Such machines are classified under three headings:

1. The Rhumkorff, or induction coil.
2. The Tesla, or high frequency coil.
3. The Interrupterless transformer.

THE RHUMKORFF, OR INDUCTION COIL.

The Rhumkorff, or induction coil, is perhaps the most common type of x-ray machine in use today. Its principles of construction may be briefly described by stating that it consists of three essential parts, of which two are coils of wire, one contained within the other, although they have not electrical connection, and the third, an instrument known as an interrupter.

The inner coil, or primary as it is called, consists of a few turns of very coarse wire wrapped about a core of soft iron, which is known as the magnetic core. The outer coil or secondary, is made up of a great many turns of fine

Fig. 2.—Diagram of the induction coil. *C*, induction coil; *P*, "the primary;" *S*, "the secondary;" *E*, electrolytic interrupter in circuit with the primary coil; *I*, rheostat and inductance control; *X*, x-ray tube connected to the terminals of the secondary coil.

insulated wire. The principles of construction of the induction are shown in Fig. 1.

The other requisite of the induction coil as mentioned, namely, the interrupter, is attached in circuit with the primary coil, and serves the purpose of rapidly interrupting the primary current which is necessary to produce and maintain the phenomenon of electro-magnetic induction. (See Fig. 2.)

The current which is taken from the x-ray machine and passed through the x-ray tube, comes from the terminals of the secondary coil, and is an induced current, produced by the magnetic field of the primary coil. As everyone is more or less familiar with the principles of electro-magnetic induction the writer will not discuss the subject to any extent. Suffice it to say here that the voltage of the transformed or induced current coming from the terminals of the secondary coil depends upon the ratio existing between the num-

ber of turns of wire in the primary and the number of turns of wire in the secondary.

If an induction coil is constructed with the same number of turns in the secondary as are present in the primary, the current induced in the secondary will be exactly equal to the current passed through the primary. The voltage will not be increased. On the other hand, if the secondary contains twice as many turns as the primary, the induced current will be double the voltage of the primary as each turn of the secondary induces a current in the turn directly adjacent to it, which must be added to the current induced in the first layer by the action of the primary current. Therefore, as we increase the number of turns in the secondary, we increase the E. M. F. or voltage.

It has been estimated that in a 12 inch induction coil, the secondary is

Fig. 3.—Diagram of the electrolytic interrupter. *P*, terminal of the positive electrode; *N*, terminal of the negative electrode; *T*, porcelain sheath or tube covering the positive electrode; *I*, platinum point of the positive electrode; *L*, negative electrode constructed of lead.

wound with between twenty and thirty miles of wire. This, of course, makes possible an enormous number of turns of wire, so that when we consider each turn of the secondary induces a current in the turn directly adjacent to it, which must be added to the current induced in the first layer by the action of the primary current, the sum total of the voltage of the current coming from the secondary amounts to something tremendous.

Another phenomenon not to be lost sight of, is that as the voltage or E. M. F. is increased, in the before described manner, the amperage or current strength is decreased in equal ratio. It will be seen, therefore, that the original current running to the primary is not changed in actual value but is simply transformed to a state or condition where it will do the special work required of it.

As stated previously, the phenomenon of electro-magnetic induction is

maintained by an instrument which rapidly interrupts, or in other words "makes" or "breaks" the primary current.

Two classes of these instruments are made, both of which utilize some automatic principle, and are known as "mechanical" and "electrolytic."

Mechanical interrupters, a simple illustration of which is the ordinary vibrator used on small coils, electric bells, etc., will rapidly make or break the primary current and thereby induce a fairly constant current in the secondary;

Fig. 4.—Induction coil, cabinet type.

but this form of interrupter has not been found to be as satisfactory for x-ray work as the electrolytic type.

Of the various forms of *electrolytic interrupters*, the Wennelt type is the most universally used. It consists of a large battery jar which is nearly filled with a solution composed of sulphuric acid, one part, and water, six parts. Into this solution are introduced two electrodes. The negative electrode is constructed of lead and has a large surface exposed, while the positive electrode is contained within a porcelain or hard rubber tube extending down into the solution with only the tip or end of the electrode exposed. The tip of

this electrode is usually made of platinum. Such an instrument is diagrammatically shown in Fig. 3.

The electrolytic interrupter is connected in the primary circuit and operates briefly as follows: As the current passes from the platinum point (the

Fig. 5.—Induction coil, cabinet type.

positive electrode) through the solution to the negative electrode, by virtue of its chemical action upon the solution, bubbles of gas are formed around the exposed platinum point. These bubbles act as a source of insulation and the current ceases to flow—it is *interrupted*. At the instant it is interrupted, the bubbles are dispersed, the solution again comes in contact with the electrode,

and the current is reestablished only to be broken again, and so on; these changes taking place with tremendous frequency. With such an instrument the primary current may be interrupted from 60 to 30,000 times per minute. These interrupters are sometimes constructed with several platinum points which makes possible a greater amperage in the current without decreasing the rate of interruptions. For dental radiography, however, a single point inter-

Fig. 6.—Induction coil with tube stand attached.

Fig. 7.—Induction coil of cabinet type.

rupter will usually suffice, and at most, not more than a two point interrupter need be used.

The interrupter, then, serves the purpose of creating the magnetic impulses which keep a constant current flowing from the secondary. We should bear in mind, however, that the currents produced by the "make" and "break" are not of equal strength, the current produced at the "break" having much the highest value. Due to the fact that this current is the strongest, and that the magnetic impulses come from the same direction (as the induction coil is used on the direct current) it prevails over the weaker. Therefore the induced or

secondary current which we use to energize the x-ray tube is the current which is created at the instant of the **break**.

The other wave, or that created by the "make," is current in the wrong direction, and is called "inverse current." In some induction coils this inverse current is the source of much trouble and where it is present to any appreciable extent, will result in blurred radiographs. It can be controlled, however, by the use of "valve tubes," or a "spark gap," arranged in series with the x-ray tube, the valve tube or spark gap serving the function of cutting out the weaker or

Fig. 8.—Induction coil constructed so that it may be attached to the wall.

inverse current, without interfering to any appreciable extent with the stronger current which is delivered to the terminals of the x-ray tube.

The induction coil is used on the direct current of 110 or 220 volts. Where only the alternating current is available, some means must be used to change the current from alternating to direct before it enters the primary circuit of the coil.

This change in the current can be accomplished by the use of a "rotary converter" of which several makes are available, or by a "chemical rectifier." These rectifiers generally consist of two electrodes immersed in a solution of

Fig. 9.—Diagram of the high frequency coil. *T*, alternating current transformer; *C*, condenser; *G*, spark gap; *R*, oscillation transformer; *D*, high tension discharge gap; *X*, high frequency x-ray tube.

Fig. 10.—Tesla coil of the portable type.

Fig. 11.—Tesla coil of the portable type.

the phosphate salts of potassium, sodium, or ammonium, one electrode being made of aluminum, and the other of lead, or carbon. When working properly, the current will flow to the aluminum through the solution, but not away from it, thus cutting out one wave of the alternating current, or it is possible, by properly connecting up three or four jars containing the electrodes, to utilize both waves of the current.

Induction coils are usually rated as to power by the maximum width of the secondary spark gap. That is, the amount of distance the spark will jump between the secondary terminals. For example, a 12-inch induction coil is capable of producing a spark which will jump twelve inches of atmosphere. While these coils are made in various sizes, capable of producing a spark from six

Fig. 12.—Tesla coil, adapted for attachment to the office wall.

Fig. 13.—Tesla coil, adapted for attachment to the office wall.

inches to forty inches in length, there is no particular advantage in using more than a 12-inch coil for dental radiography. Figs. 4, 5, 6, 7, and 8 show 12-inch induction coils constructed especially for the dental x-ray laboratory.

TESLA OR HIGH FREQUENCY COIL.

The Tesla, or high frequency, coil differs considerably in construction from the induction coil, although many of its principles are the same. In a way it is a double induction coil with the secondary of one coil acting as the primary of the other coil. An alternating current is utilized in the primary of the first coil and by means of the secondary of this same coil, is stepped up to a high voltage. This stepped up current is then carried to a condenser. As the current leaves the condenser it is oscillating at a great rate of frequency and passes into the primary of the Tesla or second coil where it induces a current in the

Fig. 14.—Tesla coil, cabinet type.

Fig. 15.—Tesla coil. Completely inclosed when not in use.

Fig. 16.—Tesla coil.

Fig. 17.—Tesla coil. Completely inclosed when not in use.

secondary of this coil. From the terminals of the last secondary, it is carried to the x-ray tube. The principles involved in this type of apparatus are shown in Fig. 9.

Like the current of the induction coil, the current from the Tesla coil is

Fig. 18.—Tesla coil, cabinet type.

Fig. 19.—Tesla coil, mounted upon movable standard.

high in voltage and low in amperage, but, unlike the current from the induction coil, it is not unidirectional, but is alternating in character. For this reason, it is considered by some as being less desirable for radiographic purposes. However, this apparently objectionable feature is overcome by using an x-ray tube

constructed in such a way as to cut out one wave of the current and thereby produce practically the same result as where an unidirectional current is used.

These coils have the advantage of being less cumbersome, require less space, and are less expensive than the other forms of apparatus, but they cannot be depended upon to do the character of work which the powerful "induction coil" or "interrupterless transformer" will do. Notwithstanding this fact, this type of apparatus undoubtedly has a place in the x-ray laboratory of the dentist, and if constructed along proper lines, can render splendid service. Figs.

Fig. 20.—The working principles of the interrupterless transformer are here shown. The synchronous motor used to operate the rectifying switch of the alternating current machine may also be used as a rotary converter where the direct current is desired for other purposes in the laboratory.

10 and 11 show Tesla coils of the portable type. Figs. 12, 13, 14, 15, 16, 17, 18 and 19 show Tesla coils which are larger and much more powerful than the portable type.

INTERRUPTERLESS TRANSFORMERS.

The interrupterless transformer is the newest and by all means the most powerful x-ray machine made. Aside from controlling and measuring apparatus, it consists of three principal parts, a rotary converter, if direct current is the source of supply, or a synchronous motor if the alternating current is the source of supply, a step-up transformer, and a rectifying switch.

Two types of these machines are made: viz., a direct current machine and an alternating current machine, the underlying principles of which are shown in Fig. 20.

Fig. 21.—Interrupterless transformer.

Fig. 22.—Interrupterless transformer.

Fig. 23.—Interrupterless transformer.

When used on the direct current, the rotary converter is set in motion and generates an alternating current which is sent through the primary of the step-up transformer. This induces a current in the secondary of the proper voltage, but alternating in character. The rectifying switch then changes this cur-

Fig. 24.—Interrupterless transformer.

rent from an alternating to a direct current and as such it is delivered to the terminals of the tube.

The alternating current machine differs only from the direct current machine in that the alternating current is run directly into the primary of the step-up transformer. This induces a current in the secondary of the proper

voltage but alternating in character. The rectifying switch then changes this high voltage alternating current to a direct current, and as such it is carried to the terminals of the tube.

The interrupterless transformer is, as stated before, the most powerful and efficient type of apparatus available for x-ray work. It is likewise the most expensive,—perhaps too expensive to be considered for the x-ray laboratory of the average practitioner of dentistry, in view of the fact that with the induction coil and other less expensive apparatus such excellent results can be

Fig. 25.—Interrupterless transformer.

obtained. Figs. 21, 22, 23, 24, 25, 26 and 27 show interrupterless transformers constructed especially for the dental x-ray laboratory.

The preceding remark, however, should not be construed as an argument against the interrupterless transformer. To the prospective purchaser who desires the very best, regardless of expense, or who expects to do a great deal of radiography, the initial expense should not be the prime consideration, as oftentimes the most expensive things in the long run prove a matter of economy.

In conclusion, I would emphasize the fact that the character of the radiography which any physician or dentist is able to do, does not depend entirely upon the excellence of his laboratory equipment. Instances could easily be

Figs. 26 and 27.—Type of interrupterless transformer.

cited where the best of equipment fails to produce the highest type of results, and vice versa, where unpretentious equipment in some hands has proved more than satisfactory. After all, the comparative degree of efficiency of the various types of x-ray machines must depend largely upon the judgment and skill of those who operate them.