the resistance of the circuit outside the electrode, plus a variable, which is inversely proportional to the periphery of the electrodes, and which represents the resistance of the surface under the electrodes.

From the preceding facts we learn that in electro-medical work, if we wish to get the current well spread under the electrodes, the latter should have a resistance at least equal to that of the skin. In the treatment of neuralgia by the introduction of the salicylic ions, the whole region innervated by the affected nerve should be covered by absorbent cotton-wool impregnated with a solution of salicylate of soda, and this should be joined up to the negative pole. If the electrode is much more conducting than the skin, the salicylic ion will be introduced only at the periphery of the electrode, outside the region of the nerve. The therapeutic action will thus be insignificant or null.

These facts show why electric baths, which are usually considered to be excellent electrodes, are in reality very imperfect electrodes. They are usually better conductors than the skin, in which case the current does not penetrate into the body except at the periphery of the electrode —that is, at the line of intersection of the skin with the surface of the water in the bath. Thus, instead of an electrode with a large surface, one has only a linear electrode of small surface. Absorbent cotton-wool, on the other hand, makes a very good electrode, since it increases the resistance without diluting the saline solution employed. In this way the resistance of a given solution may be doubled by impregnating absorbent cotton-wool with the solution and squeezing it out.

In the application of medical electricity it is found that the density of the current which can be supported with safety to the skin is less with a large than with a small electrode. This fact, which had been observed by all electro-therapeutists, was not hitherto capable of explanation. It is a result of the peripheral distribution of the current, and is due to the fact that when the electrode is increased in size, the periphery is increased less than the area. An electrode 10 centimetres square has a surface twenty-five times as large as one 2 centimetres square, whereas its perimeter is only five times as long. Hence, since current density is measured by the intensity per unit area, if all the current really passes only through the edge of the electrode, the intensity at that edge will be five times as great as with the smaller electrode, and thus much in excess of the tolerance of the patient.

A NEW ROENTGEN GENERATOR.*

By H. CLYDE SNOOK, A.M., Philadelphia, U.S.A.

This new Roentgen generator is the final result obtained after a systematic study of the induction coil, begun by the speaker in 1902.

Two principal results have been the aim of all investigators who have attempted to improve the induction coil for Roentgen work. The first of these is the complete suppression or effacement of the inverse discharge. The second is the ability to increase the useful secondary current without limit, and whilst so doing to introduce no new undesirable conditions.

This new machine accomplishes both of these results, since it delivers *absolutely no inverse discharge;* and there is no practical limitation to the electrical energy output for which it may be constructed.

By means of this machine it is comparatively a simple matter to liberate several kilowatts of energy in a Roentgen tube, and yet to have none of the current flowing through the tube in the wrong direction.

A paper by the speaker in the *Journal of the Franklin Institute* for October, 1907, describes a synchronous series spark-gap which, operating in conjunction with a mercury jet interrupter, served to open the secondary circuit of an induction coil at the phase of "make" and to close it at the phase of "break." The operation of this spark-gap synchronously with the interrupter permitted the "direct" secondary spark to pass through the Roentgen tube, but prevented the passage of the inverse at the time of make. This arrangement did not, however, prevent all inverse current from entering the Roentgen tube, because of the oscillations of the condenser used to suppress the arc at the contacts of the interrupter. Since this synchronous series spark-gap was applicable only to a mechanical interruptor of some kind with a condenser, and could not be used with an electrolytic interrupter, the necessity arose of devising a new apparatus for this purpose.

Several mechanical interrupters were devised to break heavy currents and to operate without condensers, so that a series spark-gap in the secondary circuit could be operated synchronously, and prevent the passage of the inverse due to the make of the interrupter. With these there would be no inverse due to a condenser.

Ordinary induction coils were tested with this method of operation, as well as closed magnetic circuit trans-

* Read before the Fourth International Congress at Amsterdam.

formers, when it was observed that the secondary spark at make—particularly in the case of the closed magnetic circuit transformers—was much heavier than that at break. This effect was found to be still greater when the iron of the closed magnetic circuit was magnetized in a direction opposite to the direction of the flux produced by the make current. This effect was due, of course, to the hysteresis of the iron, which, though well understood, would not have justified a prediction of the very marked difference really obtained.

The phase of the synchronous series spark-gap was then shifted 180 degrees, so that the secondary current at make was utilized instead of that at break. Since the secondary voltage at break was higher than at make, it became necessary either to short circuit the secondary at break or to utilize this voltage by a secondary pole-changing switch. Both these things were done, and both methods were found to serve the purpose fairly well; but there was a limit to the amount of current which could be obtained, owing to the use of an interrupter, and also because the magnetic cycle was poor.

There was then devised and constructed a pole-changing interrupter which magnetized the iron of a closed magnetic circuit transformer first in one direction, followed by a make, and then in the other direction, followed by a break. In synchronism with this pole-changing interrupter, there was used a high-tension pole-changing switch in the secondary circuit. This combination of pole-changing switch in both primary and secondary circuits gave a true unidirectional secondary current with absolutely no inverse; but the output of the combination was limited by the current interrupting power of the interrupter.

A careful study of this last combination showed that the iron passed through magnetic cycles equivalent to those which would result if a true alternating current were used.

It was decided to use alternating current with as nearly sine wave form as possible, for several reasons, one of which was the possibility of dispensing entirely with the services of an interrupter, and substituting for its vagaries a reliable electric generator of standard type.

The final combination, as it exists in the machine to-day, is a closed magnetic circuit transformer, which derives its primary low voltage current from an alternating current dynamo or inverted rotary converter. The transformer delivers its high-tension secondary current to a rectifying switch, which is maintained in synchronism by being mechanically attached to the dynamo or converter which produces the primary alternating current. This *mechanical* connection between the dynamo and the rectifying switch is an essential feature of the combination. Other attempts to rectify high-tension alternating currents for Roentgen work have failed partly because synchronous motors were used to drive the rectifying switches.

Synchronous motors cannot maintain the absolute synchronism obtained by the mechanical connection between the rectifying switch and the source of the current, since it is practically impossible to keep the alternations of the current absolutely constant.

When the machine derives its energy from direct current mains an inverted rotary is used. This delivers an alternating current to the transformer primary, after passing through an adjustable rheostat and a selective switch, which determines the number of primary turns and the ratio of transformation of the transformer.

When the machine derives its energy from alternating current mains, an induction motor, suited to the current supply, is used to drive mechanically, through a vertical belt drive with idler, a self-excited single phase alternator. This supplies the current to the transformer, and is mechanically connected to the rectifying switch. As in the machine which derives its energy from a direct source of supply, there is included in the transformer primary circuit an adjustable rheostat and a selective voltage switch, which controls the ratio of transformation.

Five steps are provided on this voltage switch, which control the secondary voltage from a maximum of 120,000 volts to a minimum of 70,000 volts.

The transformer is of the oil-immersed, closed-magnetic circuit core type. An essential feature of the combination is that this transformer shall have as small magnetic leakage as possible.

It is well known that in an electric circuit—

$$\tan\theta = \frac{Lp - \frac{1}{Cp}}{r}$$

and that when the circuit is linked by mutual induction to another circuit—

$$\tan\theta_2 = \frac{L_2p - \frac{1}{C_2p}}{R_2 + r_2}$$

when the self-induction and capacity are localized in the secondary circuit.

In the case of the electric circuit, including the

Roentgen tube, rectifying switch, and transformer secondary, we have the inductive reactance of the wires leading to the tube and the leakage reactance of the transformer secondary winding, as well as the capacity reactance of the tube electrodes and the switch parts. The secondary winding has an appreciable capacity, which cannot be overlooked.

Investigation of these reactances has revealed that the inductive leakage reactance of the transformer secondary is the largest one involved, and that to it is due the character of the reactance of the circuit. The flux density of the magnetic circuit is therefore kept as low as possible and the flux itself as high as possible, to keep to a minimum this leakage reactance in the core type of transformer, which is necessary with such high potentials.

In an electric circuit which has localized self-induction and capacity there will be electric oscillations having a frequency—

$$n = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

$$\text{unless } R = \sqrt{\frac{4}{C}}$$

$$\text{or if } R > \sqrt{\frac{4L}{C}}$$

These oscillations would give rise to appreciable inverse if the resistance of the circuit were not high enough to damp them effectually. The resistance of the transformer secondary alone is not sufficient for this purpose; but the synchronous rectifying switch introduces synchronously varying resistances. These effectually damp out the oscillations which would otherwise result from the capacity of the tube and secondary, which oscillate with the inductive reactance of both the primary and secondary circuits.

This type of machine has been constructed in sizes from 1 to 4 kilowatts, that being the amount of energy they are capable of delivering to a Roentgen tube.

The delivery of electrical energy to Roentgen tubes at such rates has made possible the extremely rapid exposures made by some American workers during the past year.

The advantages of this new type of Roentgen generator may be summed up as follows:

1. It delivers no inverse discharge.
2. It can be built for great capacity, and it can deliver more power than Roentgen tubes at present are manufactured to withstand.
3. It has no interrupter.
4. It has no parts liable to excessive wear or requiring adjustment.
5. It has no appreciable external magnetic field as compared with an induction coil.
6. It operates with thorough satisfaction on all kinds of currents, since on an alternating current it is far superior to any induction coil on direct current.
7. The current which it delivers can be adjusted with ease from a fraction of a milliampère to the full output of the machine.

Reports of Societies.

THE ROYAL SOCIETY OF MEDICINE—ELECTRO-THERAPEUTIC SECTION.

October 17, 1908.

THE FOURTH INTERNATIONAL CONGRESS OF MEDICAL ELECTROLOGY AND RADIOLOGY AT AMSTERDAM.

By W. Deane Butcher, M.R.C.S.,
President of the Section.

Gentlemen,—The Fourth International Congress of Electrology and Radiology was held this year at the University of Amsterdam. More than 150 years ago Holland, as you know, was the birthplace of the Leyden jar, and in that country the first record of electrical treatment dates back to 1746, when Dr. Klyn, of Amsterdam, cured a case of paralysis of the arms by means of electric sparks. Since that time a long line of Dutch physicists and physicians have contributed to the science of electricity and to the practice of electro-therapeutics; and in modern times no names are more honourably known than those of Van 'T Hoff, the great exponent of electro-chemistry; of Lorentz and Zeeman, the founders of the corpuscular theory of electricity; and of Einthoven and Wertheim Salomonson, who have endowed electro-physiology with instruments of such marvellous precision. Delegates to the Congress were sent by the Electrical Section of the Royal Society of Medicine, the Roentgen Society, and the British Medical Association; and the American Roentgen Ray Society was also represented. It is to be regretted that so few English radiologists were able to avail themselves of this unique