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SOME RECENT DEVELOPMENTS IN RADIOGRAPHY.[1]

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DURING the last few years—since 1907—there has been a rapid displacement of the induction coil by a transformer type of apparatus for radiographic work.

The transformer type of apparatus was developed in order to overcome the greatest objections to the induction coil,—namely, the use of "interrupters," very low electrical efficiency, low time factor of secondary current, and limited secondary output from practical sizes of apparatus. The transformer apparatus has successfully overcome these defects of the "coil" and has introduced no real problems of its own.

The first practical transformer type of Röntgen apparatus was installed in the Jefferson Medical Hospital of Philadelphia in June, 1907, where it still is in daily use. Since that time it has been installed in most of the laboratories of the prominent Röntgenologists and hospitals, both of this country and Europe.

It is manufactured in Europe and this country under various

[1] Presented at the Stated Meeting of the Institute held Wednesday, October 16, 1912.

names, such as "Interrupterless," "Eresco," "Transverter," "High Potential Rectifier," "Snook Röntgen Apparatus," etc.[2]

This diagram gives the electric circuits and shows the relations of the parts of the Snook apparatus, which in the sizes commonly used in modern hospitals delivers from four to ten kilowatts of electrical energy to the X-ray tube.

The high-tension rectifying switch is maintained in synchronism with the alternating high-tension secondary electromotive force of the high-tension transformer by being attached

FIG. 1.

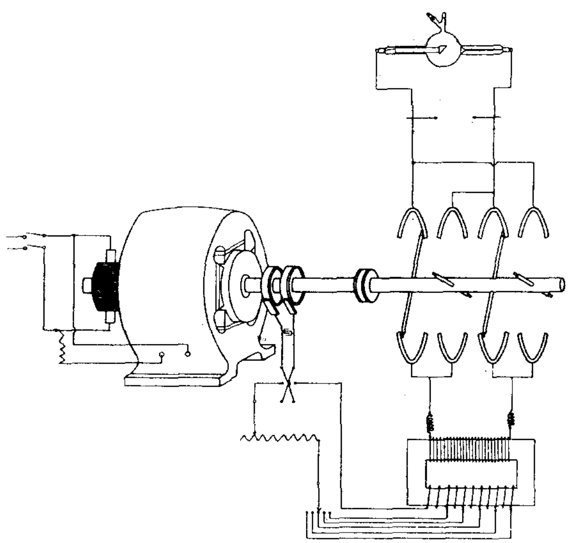


Diagram of Snook Apparatus.

mechanically to the converter generating the low-voltage alternating current, which is fed to the transformer primary.

Both the positive and negative half waves are rectified. Also, a substantial part of each half wave is collected so that the time factor of the current will be much higher than in the case of the secondary current of the induction coil. This general arrangement has enabled the manufacturers to use standard transformer construction and to standardize the apparatus on

[2] See "Die Röntgen Technik," Albers Schönberg, 1908, *Trans. Inst. Röntgen Congress; Archives Röntgen Ray*, 1908.

the basis of a wattage output, instead of a spark length rating. It has removed X-ray machines from the class of laboratory apparatus and placed them in the field of electrical engineering.

Rapid radiography of all parts of the human body has been made a matter of only a few seconds for each exposure by this apparatus, and good radiographs with uniform results from day to day are obtained with it.

It is interesting to note that various types of high potential switches have been used and developed. The balanced rotor of the original type of switch is still to-day the one that has proved to be most efficient, mechanically and electrically. A number of these devices have come out since the first one was developed; but the old type of rotor is the one that has preference to-day. It will be noticed that the rotor is a perfectly-balanced piece of apparatus. That is the idea which really made it finally win out, and it is the one that is used to-day. There have been no great improvements in this apparatus since it was placed on the market. It really remains fundamentally and electrically the same as it did when it appeared in 1907.

With it Dr. Groedel and others have developed a pseudo-bioradiographic apparatus. Some have experimented also with enormous induction coils whereby one impulse is passed through the X-ray tube for each exposure. They have succeeded in attaining a speed of about one radiograph every four or five seconds. By making reductions of these radiographs and placing them on a moving-picture film, and by running the moving-picture film through the projection apparatus, at the rate of about eighteen or twenty a second, they have succeeded in making a pseudo-moving picture of radiographic work.

This apparatus has become of some value in the study and examination of the digestive tract by the use of the "Bismuth meal." And that has led to the development of another type of apparatus, which is called the "Vertical Fluoroscopic Apparatus."

This apparatus makes it possible to examine a patient fluoroscopically in the standing position. When the digestive apparatus, with its meal of bismuth subcarbonate, has reached a stage where a radiograph is desired, a radiograph may be made. It is a highly-developed piece of apparatus. Curtains are provided which protect the operator against the secondary radiation which emanates from the patient who is within it, although the patient and operator are able to see each other through a lead glass window.

These extreme precautions are taken for the protection of the operators for the reason that X-rays in their effect upon the human body are cumulative. Like some drugs, strychnine for instance, the effect is a cumulative one, and by the repeated giving of small doses the effect is greatly increased until it becomes a dangerous dosage. The danger to the patient is practically nothing, because the patient receives only a slight dosage during his entire lifetime; but with the operator it is different, since he is working with the radiation daily.

The relation between the X-ray tube, the patient, and the operator with respect to the protective features of the apparatus is such that no X-rays can reach the X-ray operator or be detected outside of the apparatus. This is accomplished by an automatic diaphragm, a large lead box in which the X-ray tube is enclosed, and the curtains, just mentioned, which prevent the secondary radiation from the patient of the interior of the apparatus from getting outside it.

There has been developed a modification of the Snook apparatus for the Medical Department of the United States Army. This apparatus derives its power from an ordinary four-cycle air-cooled gas engine. The entire equipment, including all photographic apparatus and the necessary means of supporting the patient on the standard army stretcher while being radiographed, was made so compact that it can be loaded on one standard army wagon drawn by one pair of mules. This apparatus was exhibited by the Medical Department of the United States Army at the last International Congress of the Red Cross Society, which was held in Washington this year.

There was an exhibit of a portable army type of X-ray apparatus made by the French Government at this same Congress, arranged with and built into a large automobile. This apparatus weighed some 8000 pounds, and was awarded the Grand Prize for X-ray apparatus at the Congress.

A development which is really photographic, but which means a great deal to the X-ray operator who has a large number of plates to handle, is the improvement in stand development which has been made by Dr. David R. Bowen and Dr. G. E.

Pfahler, of Philadelphia. Economy of space is an important thing even in the Röntgen laboratory, and the efficient utilization of the cubical contents of the laboratory is a big problem with the growth of cities, the increase in density of population, and the high fixed charges on each foot of floor area.

If the X-ray operator should in one day have to develop thirty or forty plates from the 8-inch-by-10-inch size up to 14-inch-by-17-inch, and were to lay them out on horizontal trays, he would utilize a large floor area with its corresponding cubical contents. Tank development which utilizes the cubical contents of the dark room very efficiently enables the operator to develop, fix, and wash a great many more plates with a fewer number of motions than if the plates are developed in horizontal trays.

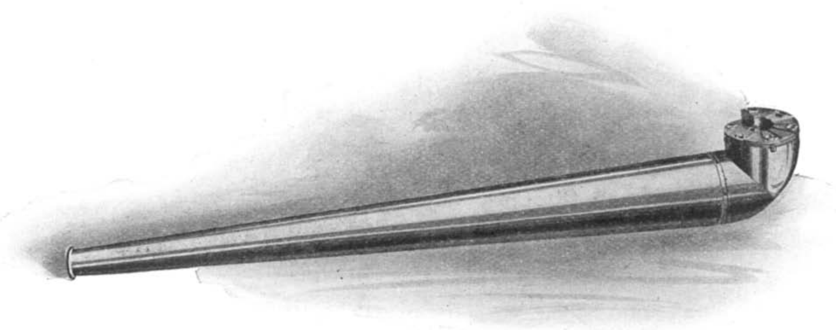
Dr. Bowen has developed a plate-holder frame which in combination with proper vertical tanks enables the operator to realize this economy in space in a most practical manner.

Several water motor types of tray rockers have somewhat displaced the noisy electric ones which up to about a year ago were most popular for the automatic rocking of photographic trays during plate development. These water motor tray rockers, while better than the electric rockers, are useful in helping to solve the problem identified with what might be termed "the retail" development of plates. The stand development, the separate frames for holding each plate—*a la* Dr. Bowen—is the best thing which yet has appeared for what might be termed the "wholesale" development of photographic or X-ray plates.

In photographic plates there has been a real development during the last year. Photographs and amateurs know full well that the rapid plate has a coarse-grained emulsion; that is to say, the general rule is that rapid plates have coarse-grained emulsions. During the last year I have tested at least three makes with fine-grained emulsions that are really quite rapid. These plates are all of English make, and American makers are doing their level best to imitate the results. One interesting thing about these rapid plates is that they have an unusually high percentage of silver. This percentage of silver is about 35 per cent. greater than any of the rest of the X-ray plates. The increased absorption of X-rays by this large percentage of silver in the emulsion is one of the things, of course, that cause the increased transformation of the X-ray energy into chemical energy and increase the speed of the plate. But there are two types of plates only that have proved very successful with fine-grained emulsions and with a much smaller percentage of silver. I do hope that our manufacturers will find out what to do to give the beautiful surface and the rapid speed of some of these English plates.

The Pfahler-Benoist penetrometer, which is used for determining the degree of penetration of the X-rays emanating from the X-ray tube, is another comparatively recent important development. This apparatus consists of a long tapering tube

FIG. 2.



Pfahler-Benoist Penetrometer.

at the large end of which is mounted the penetrometer proper. The penetrometer itself has in its centre a disk of silver 11/100 millimetre thick, and around it is placed a stairway of aluminum sectors, each step of which is one millimetre thick. Immediately behind this assemblage of sectors and silver disk is a barium platino cyanide screen. Beyond it, at an angle of 45 degrees, is a mirror arranged so that the operator by looking into the large tube can see the fluoroscopic image produced by the aluminum sectors and silver disk.

Dr. Benoist discovered the fundamental fact that 11/100 millimetre of silver offers a fairly constant absorption to Röntgen radiation of all degrees of hardness. The varying steps of aluminum thickness have variable absorption for variable degrees of X-ray penetration. The operator, therefore, simply by matching the shadow of the silver disk against the shadows of the aluminum sectors, is able to read the hardness factor of the radiation. This is the most accurate method in existence to-day by which to measure the degree of penetration of the radiation emanating from an X-ray tube.

Another important recent development is the improved Sweet eye localizer, which is the work of Dr. Wm. M. Sweet, a celebrated eye surgeon, who for a number of years has used the eye localizer which he has tried to get other people to use, but has been somewhat unsuccessful because of the difficult technique. This new apparatus was developed by Dr. Sweet so that the difficulties of technique could be reduced to mechanical operations.

A focal co-ordinate reference plate and a reference chart are used in conjunction with the radiographs to provide the proper mechanical recording of measurements which are necessary to locate the foreign body in three-dimensional space.

This apparatus was fully described by Dr. Sweet in recent articles in the *Archives of the Röntgen Ray* and elsewhere, so that a full description is omitted here.

Another development which within the last two years has made great headway in both Europe and in this country has been stereoscopic radiography. This has been due to a comparatively recent recognition of the correct optical principles which underlie proper technique in this work. Some form of Wheatstone stereoscope is usually employed.

The obvious advantages of this method of procedure in radiography do not require elaboration. The advantage of having the parts radiographed in three dimensions,—that is, stereoscopically,—is very great in the cases of fractures, foreign bodies, skull and lung examinations.

Recent developments in the quality of intensifying screens have enabled the X-ray operator to increase the speed with which he makes radiographs, so that about one-fourth the former time of exposure is required. The modern intensifying screen consists, usually, of a piece of cardboard, one side of which has a coating of calcium tungstate.

Mr. Edison and others, shortly after Röntgen made his discovery, experimented with various kinds of intensifying screens.

The crystals of these early intensifying screens were too large to be of practical use, because of the mottling which they produced on the photographic plates. The surface of the early screens was very rough indeed, while the surface and the size of the particles in the sensitive side of the modern intensifying screen are usually smaller than the grain of the photographic emulsion. The modern screen, therefore, does not cause an appreciable mottling of the photographic plate.

The radiographs are usually taken with the radiation passing through the photographic plate before the radiation strikes the screen, because of the fact that X-ray absorption of the tungsten salt is greater and less uniform than the absorption of the glass plate and the photographic emulsion. These screens all give a bluish-white light, so that they are quite efficient in producing actinic effects upon the photographic emulsion.

The developments in X-ray tubes recently appearing include the so-called Bauer air regulator, which is a device for admitting ordinary atmospheric air into X-ray tubes from time to time when the vacuum of the tube needs reducing.

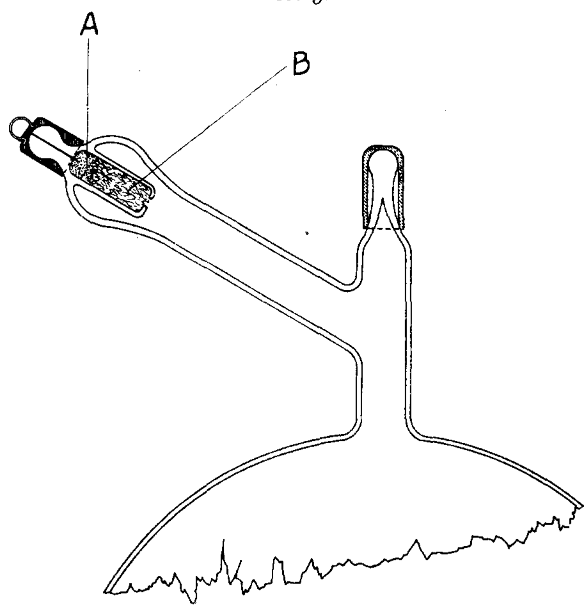
The regulator has attached to it a large rubber tube and a rubber bulb or other device that may be squeezed in order to compress the column of air in the rubber tube, which in turn pushes a small column of mercury in a capillary tube, and this by its movement exposes a plug of porous material through which a small amount of atmospheric air may diffuse into the X-ray tube.

This regulator has proved to be quite satisfactory and is used to a large extent in Europe, because of the fact that atmospheric air gives a better characteristic to the vacuum of the X-ray tube than the gases admitted by the ordinary chemical regulators previously in vogue. This is a deserving and meritorious improvement which has added to the ease and convenience of reducing the vacuum of the X-ray tube.

Now I have the privilege of calling your attention to what I think is the first really commercial application of radium. This, I believe, is the first announcement, and it gives me very great pleasure to have the privilege of making it to The Franklin Institute. Briefly, it is the use of a powdered uranium-radium ore in the X-ray tube regulator as a gas-producing material to liberate gaseous helium at the will of the X-ray operator.

Referring to Fig. 3, *A* is a mass of powdered clevite, Bröggerite, or other ore which, due to atomic disintegration, is constantly producing within its own volume gaseous helium or other monatomic gas. This mass of powdered mineral is mixed with a small percentage of asbestos wool in order to introduce appreciable resistance between the highly-conducting particles of crushed ore. *B* is a packing of asbestos wool for the purpose of holding *A* mechanically at the upper end of the

FIG. 3.



Helium Regulator for X-ray tubes.

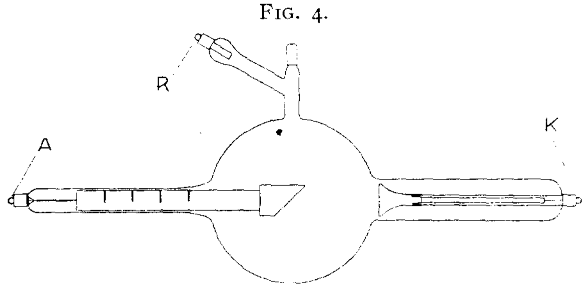
A, powdered solid containing helium gas; *B*, plug of asbestos.

glass tube within which it is contained and to keep it in contact with the conductor which leads to it through the glass seal.

Uranium is the atomic parent of radium. Radium likewise breaks down and evolves helium, due to atomic disintegration. Clevite and Bröggerite are two of the minerals which occlude the helium gas as rapidly as it is formed within its own volume. These minerals will yield this gaseous helium upon heating or upon being dissolved in strong acids. In the X-ray tube regulator the powdered mineral conveniently retains the self-generated helium gas until it is required and liberated by passing a high-tension discharge through it, which liberates the gas by heating.

The advantage which gaseous helium has in an X-ray tube is the fact that its resistance to the passage of the electric current is small as compared with the common gases or any other gases that are readily available. The dielectric cohesions, or resistances to the passage of the electric current, of the rare gases of the atmosphere are as follows: Neon, 8.5; helium, 18.5; argon, 120, while that of air itself is 460. It is seen that neon would be more suitable as a gas to make the electrical resistance of the X-ray tube low than helium itself. Neon, however, is

FIG. 4.



X-ray tube with Helium Regulator.

A, Anode; *K*, Kathode; *R*, Regulator.

not readily obtainable, is exceedingly rare, and is not conveniently capable of being used in the X-ray tube in even the small commercial quantity needed for X-ray tubes.

Helium is the best available gas, since Nature has kindly provided the uranium minerals which generate and hold the helium gas until it can be liberated in a tube regulator, in the manner above described.

I make this statement because I believe that the dielectric cohesion of neon is the lowest of all the known gases, and because helium is next to neon in its low electrical resistance.

The so-called "crankiness" of X-ray tubes which X-ray operators find in the case of old X-ray tubes is due to the presence in the X-ray tube of gases of very high dielectric cohesion. These gases are set free by electric discharge through X-ray tube regulators provided with mica, or asbestos, near the end of the life of these gas-producing materials when used as such in X-ray tube regulators. Glass itself gives off gas having very high dielectric cohesion when the glass is heated in a vacuum. Since this condition exists in an X-ray tube when strongly operated, the inner surfaces of the walls of the X-ray tube liberate gases having high electrical resistance and thereby producing the so-called "cranky" tube.

Tubes with these helium-radium-uranium regulators do not exhibit the crankiness above described and give a larger percentage of X-ray energy output for a given input of electrical energy than X-ray tubes otherwise identical except of the kind of gases used to regulate them. This increase in X-ray energy output for a given electrical energy input is approximately 20 per cent. as compared with similar X-ray tubes using atmospheric air for their regulation.

It is an exceedingly fascinating idea to realize that the helium gas within an X-ray tube using one of these radium regulators is obliged within the X-ray tube for a second time to perform the function of being the matter or stuff connected with the production of corpuscles and positively-charged carriers of electricity. In the atomic disintegration of the radium this helium was the very identical matter constituting the alpha particles given off by the radium. Now in the X-ray tube it is again required to furnish the material from which are made the positive particles which correspond to the alpha rays of radium and the kathode rays which correspond to the beta rays of radium.

Discussion.

DR. GOLDSCHMIDT.—I would like to ask how recent that fluorescent screen is.

MR. SNOOK.—This calcium tungstate intensifying screen has been in practical use really since 1910, but the practical development of the screen so that it would withstand rough usage has occurred only within the last year. The matrix,—that is to say, the binder, with which the crystals of the salt were held together,—was originally a soluble gum. The result was that finger-prints would show very quickly. The later screens, which have been made practical this year, have had a matrix of celluloid or nitrated cellulose, so that they are quite durable, and do not show finger-prints. They actually can be wiped with a damp cloth.

A MEMBER.—I am surprised about the statement that the small crystals are visible. Years ago I examined such a plate with a contact lens, and I could not see any crystals; I could see a fine powder.

MR. SNOOK.—That is really true. It is practically large crystals powdered; but in the powder one finds many very fine crystals.

A MEMBER.—Well, sulphide of zinc is used for the same purpose, is it not?

MR. SNOOK.—No, it is too strongly phosphorescent, and does not exhibit so high an efficiency; it is not an efficient transformer of X-rays into light.

Q.—It is rather weak, is it not?

A.—Yes.

MR. HORNOR.—Do you use tungsten electrodes?

MR. SNOOK.—There are so many things that might have been brought to your attention, and I beg your pardon for having failed to call your attention to that phase of the subject.

The focus spot of the X-ray tube must be made of a material that will withstand very high temperatures. It must also be strong mechanically and have good thermal conductivity. Such a material, with better thermal conductivity and with a higher melting point and better mechanical properties than the material we have used until a year ago, is to be found in the ductile tungsten which has been placed on the market by the General Electric Company. The material which was used prior to the use of tungsten was usually platinum or a platinum-iridium alloy. Perhaps 20 per cent. was the highest successful percentage of iridium alloyed with platinum. Iridium has a higher melting point than platinum, and alloyed with platinum raises the melting point and thus makes a target with good resistance.

Prior to the introduction of tungsten the target had a melting point of about 1750° centigrade, whereas the melting point of tungsten is approximately 3000° C. When you realize its thermal conductivity,—that is, when you consider the ability of the metal to conduct the heat away from the focus spot (the tungsten has about twice that of platinum when the tungsten is first placed in the tube),—it has an enormous advantage over platinum or its alloys that has been an exceedingly great help

MR. G. R. HORNOR.—Did I understand you to say that helium made a tube more efficient than argon?

MR. SNOOK.—Considerably. And argon is more efficient than atmospheric air, and atmospheric air is more efficient than the oxygen which is obtained from such materials as potassium chlorate, manganese dioxide, and other chemicals which on heating will give off gaseous oxygen. Argon is more efficient than nitrogen, but helium is the most efficient gas I have been privileged to use.

MR. HORNER.—Did you say that radium itself disintegrates into helium gas?

MR. SNOOK.—Yes, it does. One of the earliest experiments was to place some radium in an X-ray tube, and the idea was to utilize the helium given off by radium. Radium, however, does not hold gaseous helium, but gives it off freely, and therefore the free gas in the tube constantly became of greater and greater pressure and the vacuum went down in a most disappointing manner; whereas with the minerals we use the helium does not become a free gas until the mineral is heated by the electric discharge, when desired.

MR. HORNOR.—How do you introduce the free gas into the tube?

MR. SNOOK.—I will demonstrate by the tube on the machine. (*Practical demonstration.*) It will be seen that the main terminals of the generating apparatus are directly connected to the main terminals of the X-ray tube. It will be seen also that the regulator terminal is insulated by not being connected to anything. If now I rotate this arm, so as to get the high tension over from the anode to the regulating terminal, I can pass the discharge through the X-ray tube regulator. I will demonstrate this. (*Demonstration.*)

Now, changing the connection back, we measure the parallel spark gap in that distance, and it is less than 2½ inches. Changing it back and lowering it again, we have a little over 1½ inches.