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NOTE ON THE DIAGNOSTIC AND THERAPEUTIC VALUE OF THE COOLIDGE TUBE.

BY

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NOTE ON THE DIAGNOSTIC AND THERAPEUTIC VALUE OF THE COOLIDGE TUBE.

ON December 27 last the author had the honour of introducing to an assembly of his American associates a man who has accomplished more for the advancement of this science than anyone except Roentgen himself.

William David Coolidge, D.S., Ph.D., is a graduate of the Boston Institute of Technology and of the University of Leipzig. At present he is engaged in research work at the experimental laboratories of the General Electric Company at Schenectady, N.Y. Among other important achievements, he has succeeded in producing ductile tungsten, by the use of which he has devised the ignition system for gas-engines and electric furnaces. While engaged in experimental work on the substitution of tungsten in place of platinum for the anode of an X-ray tube, he was led to construct a tube on entirely new principles.

He believed that if a tube could be devised which should be entirely free from gas many of the disadvantages of the ordinary tube would be removed. He introduced a cathode and anode of tungsten, supported by the sister metal molybdenum, which substances are more readily freed from gas than the metals used in the ordinary tube. In this way he was able to procure a vacuum 1,000 times more attenuated than that of the ordinary tube. Dr. Coolidge's associate, Dr. Langmuir, found that a tungsten cathode, heated in a highly evacuated bulb, would emit a stream of negative electrons, and thus provided the foundation upon which Dr. Coolidge developed his subsequent work.

An abstract of Dr. Coolidge's own report of the new focus-tube, published in the *Physical Review* of December, 1913, appears in another portion of this journal. I will merely mention the important features wherein it differs from other tubes.

The cathode of the Coolidge tube consists of a spiral tungsten filament which, when electrically heated, gives off the stream of negative electrons required for the generation of the X rays. A molybdenum sleeve around the spiral filament is used to focus the cathode stream upon the target. Both anode and cathode are made of tungsten. The number of electrons given off from the cathode is regulated by changing the temperature of the tungsten spiral. The speed of the cathode stream, and therewith the

penetrating power of the X rays, can be regulated by increasing or diminishing the voltage on the terminals of the tube.

None but a radiographer can realise the practical advantages resulting from this mode of construction—viz., accuracy of adjustment, stability of hardness, exact duplication of results, fixity of the focal point, long life, flexibility, tremendous output, and absence of indirect rays.

In the ordinary tube the penetration depends entirely upon the adjustment of its vacuum by some regulating device—a method which is both inaccurate and most unfavourable to uniform results, since the vacuum is difficult to adjust and hard to sustain—whereas the hardness of the Coolidge tube can be adjusted to perfect accuracy by simply regulating the current through the tungsten filament of the cathode.

The stability of the tube is no less remarkable. In laboratory tests it has been run for fifty minutes without any adjustment, and with no perceptible variation in hardness, whereas an ordinary tube cannot be operated for more than a few seconds without showing material changes in penetration.

Up to the present time radiologists have found it practically impossible to obtain brilliant Roentgenograms with any degree of uniformity. With the new tube it is possible accurately to adjust and sustain a given degree of penetration, thus enabling us to obtain exact duplication of previous results. The Roentgenograms obtained with the new tube are not, indeed, more brilliant than selected radiograms obtained occasionally with ordinary tubes, but extraordinary detail of soft tissues, tendons and bloodvessels, may be obtained with a far greater degree of certainty than heretofore.

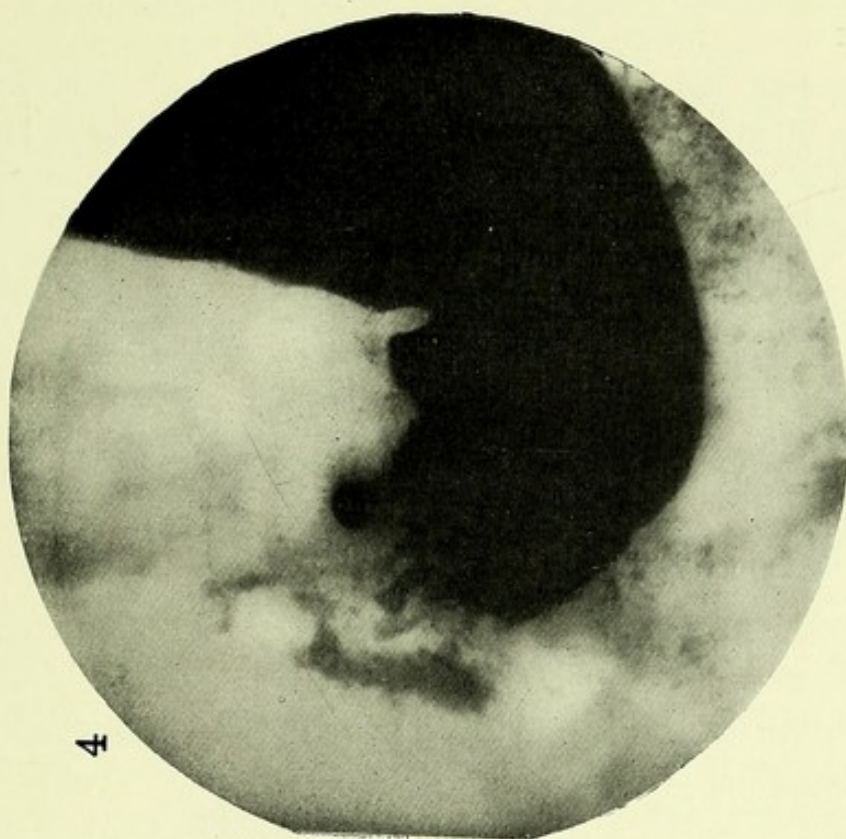
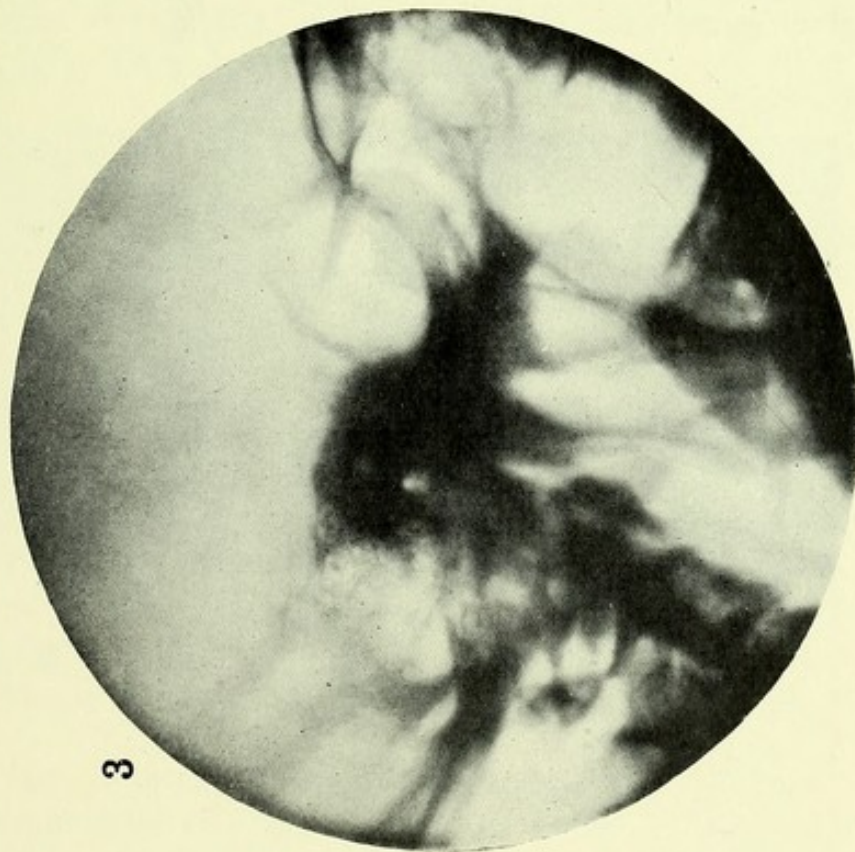
In the ordinary tube, variability of the focal spot is a factor which is often responsible for blurring of the image, whereas in the Coolidge tube the focal spot is an absolutely fixed point.

With an ordinary tube flexibility is impossible. To obtain Roentgenograms of various portions of the body, a great number of tubes of different degrees of penetration are required, whereas the new tube adapts itself to every kind of Roentgenographic and therapeutic work. It can be instantly altered from a soft tube, showing the bloodvessels in an infant's arm, to a hardness never heretofore obtained, and can be maintained at any given degree of hardness for an indefinite time.

The working life of the new tube has been estimated by Dr. Coolidge to be at least a thousand hours of constant running, a great increase over the life of the old tubes.

Its tremendous output, both for diagnostic and therapeutic purposes, is perhaps the most wonderful advantage of the tube, making it especially useful in the Roentgenkinematography of the stomach and heart and in radiotherapy of deep-seated cancers.

The complete absence of indirect rays in the Coolidge tube is of great scientific interest and of practical value. The positive bodies in the ordinary tube are a useless and harmful by-product, and their elimination suppresses entirely both the intense heating of the tube and the fluorescence of the glass



THE DIAGNOSTIC AND THERAPEUTIC VALUE OF THE COOLIDGE TUBE.
By DR. L. GREGORY COLE.

PLATE CCCCXXVI.

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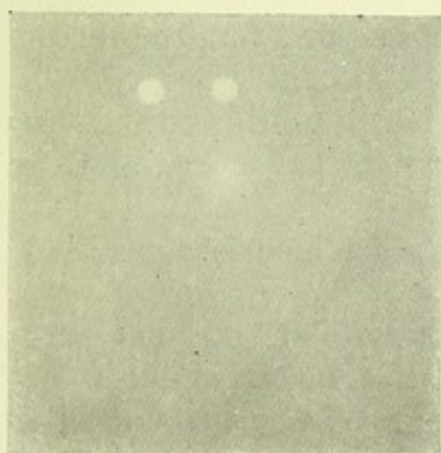
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wall. In the author's laboratory the tube is already being used for routine diagnostic and therapeutic work.

A scale of hardness and milliampère-seconds necessary for the correct exposure of any part of the body is appended, but this is only a rough indication which will require further verification.

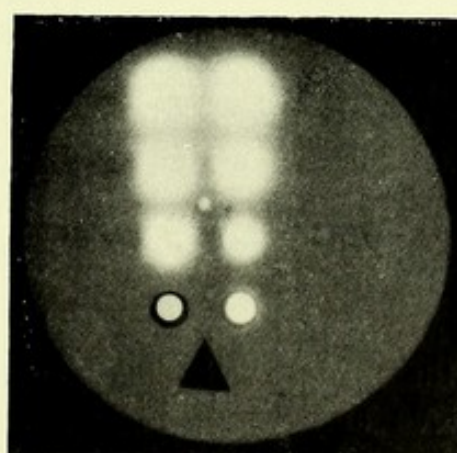
	SPARK-GAP.	CURRENT.	TIME.	MILLIAMPERE-SECONDS.
	Inches.	Milliampères.	Seconds.	
Hand : soft parts	1½-2	25	2	50
Knee : soft parts	3	25	4	100
„ bone and soft parts	4	25	4-5	125
Hip-bone	5	30	15	450
Kidney	4	30	15	450
Spine : bone detail	5	30	15	450
Head : lateral	5	30	15	450
„ A.P.	5½	40	15	600
Lungs	3	40	10	400
Stomach (screen)	5	100	·06	6

In its therapeutic application, the tremendous output of this tube, with high penetration, gives a variety of X ray which is more like the gamma rays of radium than ordinary X rays. The treatment of deep tumours, as described by Kroenig and Gauss, which heretofore has required three to six hours, may now be accomplished in thirty to sixty minutes. Such a tremendous volume of highly-penetrating X rays will permit the use of adequate filters for protecting the skin, and it is to be hoped that the new tube will supplement, or replace in great part, the use of radium.



A.

Spark-gap, ¾ inch.
Current, 10 milliampères.
Exposure, 10 seconds.



B.

Spark-gap, 8 inches.
Current, 10 milliampères.
Exposure, 12 seconds.

The accompanying figures show two Roentgenograms of the Walter penetrometer to demonstrate the flexibility of the tube. A was made with an exceedingly soft tube, the parallel spark-gap being under 1 inch. B was made an instant later with the same tube, adjusted to a penetration that read

beyond the Walter scale. It will be seen that the rays readily passed through the thickest platinum disc, and even through the surrounding lead.

The following tests will show the therapeutic efficiency of the Coolidge tube. For these experiments a Hampson radiometer was used. A piece of beef 2 inches thick was irradiated by a Coolidge tube, at a focus distance of $5\frac{1}{2}$ inches. An aluminium filter 3 millimetres thick was interposed between the tube and the beef. One Sabouraud pastille was placed on the surface of the beef, a second pastille 1 inch below the surface, and a third pastille under 2 inches of beef.

Experiment I.—The tube was regulated so that the parallel spark-gap was $7\frac{3}{8}$ inches. The Bauer penetrometer indicated far beyond the registered scale. The Walter penetrometer registered 8+. An exposure of three and a half minutes was made. During this time the milliamperage varied from 10 to 8 and back to 9. The pastille on the surface read 12 H., or three times the erythema dose. The pastille 1 inch deep read 6 H., or one and a half times the erythema dose, and the pastille 2 inches below the surface 3 H., or about three-fourths of an erythema dose.

Experiment II.—The spark-gap was again $7\frac{3}{8}$ inches, the Walter penetrometer 8+, and the milliamperage from 8 to 10. An aluminium filter 3 millimetres thick was interposed, and a series of four one-minute exposures, followed by a two-minute exposure, was made on a similar piece of beef.

With a one-minute exposure the pastille on the surface read 4 H.

After the second exposure of one minute, making a total exposure of two minutes, a second pastille on the surface read 4 H. The pastille an inch deep, exposed for a total of two minutes, read 3 H.

After the third one-minute exposure, a new pastille on the surface again read 4 H. The pastille an inch deep, exposed for a total of three minutes, read 4 H.

After the fourth one-minute exposure, a fourth pastille on the surface read 4 H. The pastille an inch deep, exposed for a total of four minutes, read 6 H., and the pastille 2 inches deep read 3 H.

After a fifth exposure of two minutes, the fresh surface pastille read 8 H. The pastille 2 inches deep read 4 H.

The above tests show that by using six ports of entry one may obtain a full erythema dose 2 inches below the surface in six minutes. With this tremendous amount of highly-penetrating rays, any amount of screening desirable may be used without prolonging the treatment beyond a reasonable time.

It must be noted, however, that the Coolidge tube is like a two-edged sword—capable of doing great damage unless manipulated with the utmost care. The danger is especially insidious in that there is no evidence of the action of the tube during its operation. With an ordinary focus-tube a considerable exposure of several minutes is without danger to the patient. With the full capacity of the new tube, however, serious and even fatal burns may be caused in much less than a minute. A note of warning

should therefore be added to the announcement of an achievement which is undoubtedly the most remarkable of its kind in the present age.

The four radiographs shown on Plate CCCCXXXVI. give some idea of the flexibility of the new tube.

FIG. 1.—Radiograph of child's arm, taken with a Coolidge tube of exceedingly low penetration. The negative showed the contour and structure of the bones, the various layers of muscle, the pronator quadratus, bloodvessels, and lobules of subcutaneous fat, very distinctly.

Parallel spark-gap, $3\frac{1}{2}$ inches; current, 70 milliamperes; exposure, $\frac{1}{4}$ second.

FIG. 2.—Hand of a child, showing remarkable detail in the soft tissues, especially the thumb tendons.

Parallel spark-gap, 3 inches; current, 70 milliamperes; exposure, $\frac{1}{10}$ second.

FIG. 3.—Lateral view of a tumour of the hypophysis, showing distortion of the anterior and posterior clinoid processes, an area of increased density in the anterior part of the sella turcica, and a localised area of increased density in the gland. Taken immediately after Fig. 1 with the same focus-tube, but adjusted for very hard rays. The contour and structure of the bones is revealed in a manner which would lead one to believe that the Roentgenogram was made from a skull devoid of soft parts.

Parallel spark-gap, 5 inches; current, 40 milliamperes; exposure, 10 seconds.

FIG. 4.—One of a series of ten plates of the stomach. The total time required for taking the series was $\frac{6}{10}$ second. The radiograph shows a distortion of the duodenal cap due to post-pyloric ulcer.

Parallel spark-gap, $5\frac{1}{2}$ inches; current, 110 milliamperes; exposure, .06 second.

