

ART. XXVI.—*Solarization effects in Röntgen Ray Photographs*; by WM. LISPENARD ROBB. (With Plates VIII–X.)

It has long been well known, that in photographing with ordinary light, in cases of over-exposure, the picture upon development may be a positive instead of a negative. This phenomenon is known as solarization, as it is usually produced by over-exposure in strong sunlight. Also, in case of over-exposures not sufficiently long to produce a reversal of the image, the photographic plate may be so affected as to prevent satisfactory development.

Some experiments that I have recently made show that similar effects are produced by the Röntgen rays, and that they have a very important bearing upon the distinctness of photographs taken with these rays, and offer a very simple explanation of the halos that so often appear in such photographs.

The following apparatus was used in these experiments: The induction coil used was a "Thompson Inducturium" as manufactured by the General Electric Co., except that a rotary break was substituted for the one furnished with the coil. The rotary break consisted of a solid brass ring 25<sup>cm</sup> in diameter and 5<sup>cm</sup> thick. Two slate quadrants, 2.5<sup>cm</sup> thick, were counter-sunk in the ring. Two copper brushes were arranged so that one was always in contact with the brass and the other alternately with the brass and slate sectors. The ring was mounted on the shaft of a 1 h. p. motor, making 1800 revolutions per minute, and consequently the primary circuit of the induction coil was made and broken 3600 times per minute. A condenser having a capacity of six microfarads was connected with the two brushes. This was the largest condenser available; and it was found that the sparking at the brush, where the circuit was alternately made and broken, was very great, being sufficient to cause great unsteadiness in the illumination of the screen of a fluoroscope. A very simple method was found for overcoming this unsteadiness. A third brush made of mica was placed so as to be in contact with the break and to form an obtuse angle with the brush at which the sparking occurred. This additional brush prevented the sparking; and after it was adopted, the illumination of the fluorescent screen was entirely free from flickering. The current in the primary was adjusted in the following experiments so that the coil would give a spark 25<sup>cm</sup> long. Single focus vacuum tubes were used. The tubes were spherical in form, about 14<sup>cm</sup> in diameter, and the distance between the anode and cathode was about 8<sup>cm</sup>. The tubes used were made by Green & Bauer of Hartford, Con-

necticut, and by the General Electric Co. at their lamp works at Harrison, N. J. In the absence of any exact method of expressing for any given set of apparatus its power of producing Röntgen rays, the statement that the photograph of a portion of a hand reproduced in Plate VIII, fig. 1, was taken with the apparatus just described, will serve to show its character. The time of exposure was 5 seconds and the distance of the hand from the anode 25<sup>cm</sup>.

Solarization effects were first noticed by the author in connection with the halos surrounding the Röntgen ray photographs of pieces of metal. These halos were in general similar to that shown in Plate VIII, fig. 2, which is a reproduction of the photograph of an aluminum cube, the edge of which was 2.5<sup>cm</sup>. Surrounding the portion of the photographic plate directly under the cube is a band in which the plate was somewhat affected by the rays. Just outside of this first band is a second one, in which the effect upon the photographic plate was greater than upon any other part of the plate. This halo is easily explained when we consider that in a single focus tube the Röntgen rays come from a considerable area of the anode and that consequently the shadow of the object is surrounded by a penumbra in which the intensity of the radiation increases from the object outward. If the exposure is sufficient to produce solarization, we should have a band in the penumbra where the effect upon the photographic plate would be a maximum exceeding even the effect upon the part of the plate entirely beyond the shadow. The photograph reproduced in Plate VIII, fig. 2, was taken with fifteen minutes' exposure at a distance of 15<sup>cm</sup>.

The experiment was repeated with cubes of iron, copper, paraffin, and glass, all of which gave similar halos. In general, the image on the photographic plate was visible to the eye before being placed in the developer—a phenomenon that accompanies solarization when produced by ordinary light.

The following experiments were made in order to prove the correctness of the above explanation and to demonstrate the possibility of a photographic plate becoming solarized by the Röntgen rays.

Portions of several plates were covered with pieces of commercial tinfoil and then exposed in succession for different times to the action of the Röntgen rays. It was found that with short exposures a negative was obtained, and with long exposures the image was reversed; the long exposed plates giving a positive when developed. Plate IX, figs. 1 and 2, and Plate X, fig. 1, are reproductions of photographs obtained when a portion of the photographic plate was covered with one layer of commercial tinfoil about 5<sup>cm</sup> square and 0.0015<sup>cm</sup> thick, and

the central portion of this layer was covered with thirty-two additional layers of the same foil about 2.8<sup>cm</sup> square. Plate IX, fig. 1, shows the result when the plate was exposed for 2.5 minutes; fig. 2, when exposed for 5 minutes, and Plate X, fig. 1, when exposed for 15 minutes. These photographs show that with a short exposure, the portion of the plate covered with a single layer of tinfoil was less affected than the uncovered portion of the plate. When the time of exposure was increased, the shadow of the single layer of tinfoil would only be noticed on the negative by careful inspection, and might easily escape detection. In the case of the longest exposure, where the portion of the plate covered with the single layer of the tinfoil is most affected, we have a reversal of the image and a clear case of solarization.

Experiments were also made with photographic plates partially covered with an aluminum cone having an altitude of 1.25<sup>cm</sup> and a base 5<sup>cm</sup> in diameter. When the exposure was short, the uncovered portion of the plate was most affected. When the plate was placed at a distance of 15<sup>cm</sup> and exposed for 5 minutes, the effect reproduced in Plate X, fig. 2, was obtained. In this case, the portion of the plate under the edge of the cone was most affected. When the time of exposure was increased to 15 minutes, all of the plate covered by the cone was affected more than the uncovered portion, and again we have a reversal of the image and a clear case of solarization.

Seed, Kramer crown, and Carbutts' special X-ray plates, and various developers were tried and found to give similar results. Carbutts' X-ray plates and Carbutts' tabloids for developer were used in making the photographs for the accompanying illustrations.

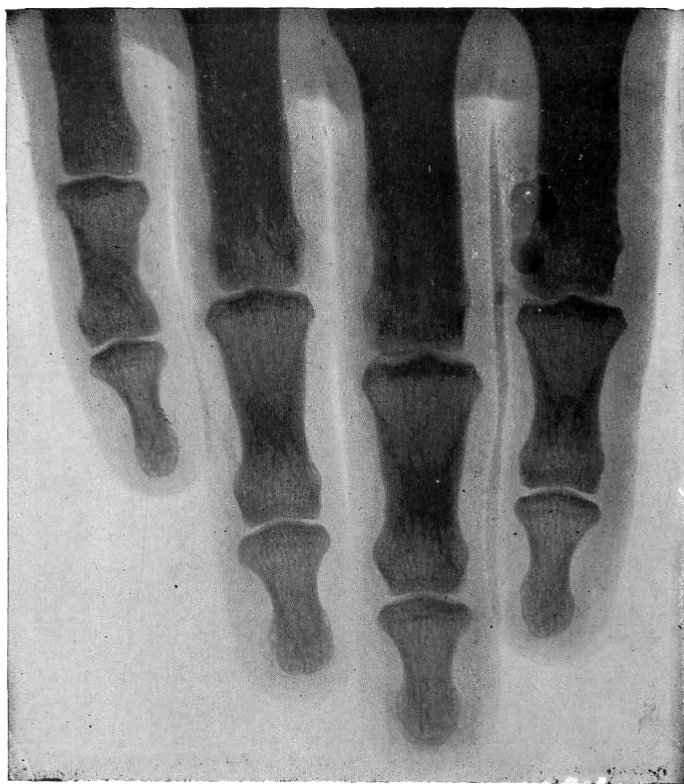
These experiments seem to prove conclusively the possibility of photographic plates becoming solarized by Röntgen rays. This is interesting as adding one more to the properties possessed in common by these rays and ordinary light. Solarization offers a simple explanation of many of the halo effects observed in Röntgen ray photographs. The most important conclusion to be derived from these experiments is the necessity of carefully timing exposures if we are to obtain good contrasts, much of the indistinctness in Röntgen ray photographs being due to over-exposure rather than to under-exposure.

I desire to express my obligation to Columbia University for the very material assistance given me in carrying on these experiments by placing at my disposal the income of the Barnard Fellowship.

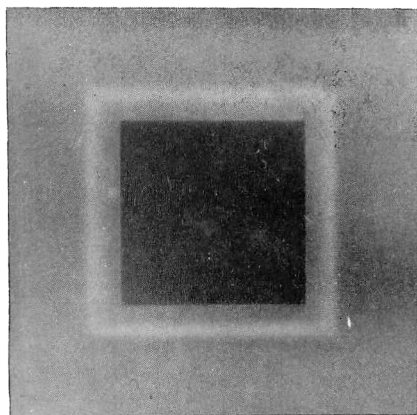
Jarvis Physical Laboratory, Trinity College,  
Hartford, Conn., July 24th, 1897.

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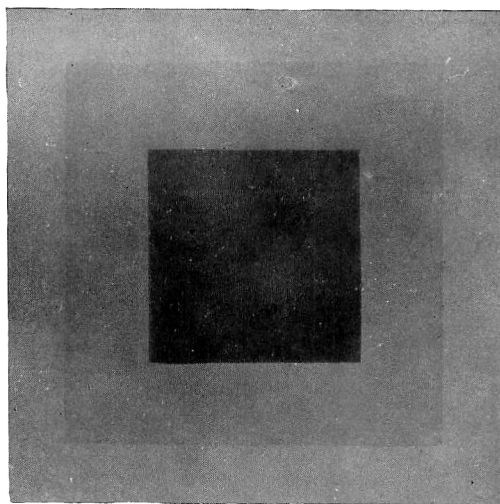
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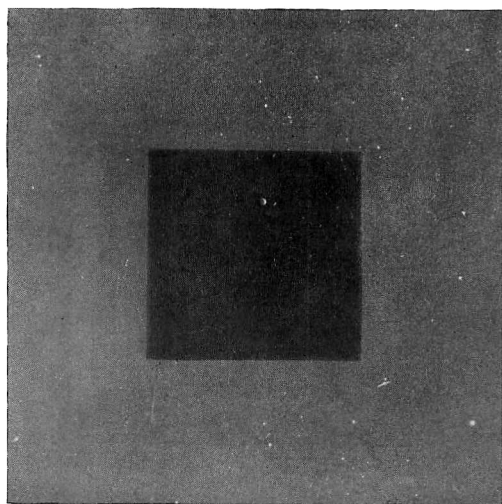
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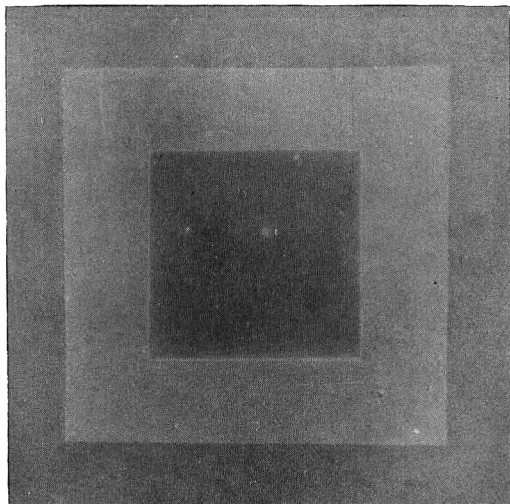
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