"Radiographic Projection

by Röntgen's Method"

being a Dissertation by

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Contents.

I Heinrich Herz ("On the Passage of Cathode Rays through thin metallic films" Wiedemann's Annalen 45. p. 28. 1892 translated in the "Electrician" April 27. 1894. p. 724) showed experimentally that the phosphorescence producing rays, proceeding from the cathode of a vacuum tube exhausted sufficiently highly to eliminate almost all the phenomena attached to the anode and those which mark the course of the electric discharge, are able to traverse thin metallic films, opaque to light rays, even in three or four thicknesses, "inside the discharge tube".

II Philipp Lenard ("On Cathode Rays in gases under Atmospheric Pressure & in extreme Vacua" Wiedemann's Ann. 2. ~~4~~. 1894 translated in the "Electrician" for March 23 & 30 & April 6 of the same year at pp. 574, 613 & 630 respectively) studied ~~Lenard~~ these Cathode Rays, after transmitting them through an aluminium "window" 1.77 mm. wide & .00265 mm. thick into an "observing space" of ordinary air. He found that "bodies capable of phosphorescing, if held near the window, glow on the side turned towards it with the light peculiar to them" "With increasing distance from the window, the phenomena

phenomena quickly decreases in intensity, dis-appearing at a distance of 6cm or 8cm." The intensity of the phenomenon depends on the distance from the "window". He mentions among other substances chalk, common glass, flint glass, pentadecylparatolylketone, & platinocyanides. Sulphate of quinine, solid & in solution also fluoresced. Bodies incapable of phosphorescence like metals remained dark. The platinocyan-ides were specially brilliant. "All phospho-rescence phenomena in the observing space cease as soon as a magnet brought near the vacuum tube deflects the Cathode Rays from the window" "The cathode rays do not affect the eye". "A quartz plate ½ mm. thick when introduced at any point between the window & the phosphorescent body entirely cuts its glowing; common gold silver or aluminium leaf allows it to remain without perceptible weakening". "The opacity of the quartz plates used & the transpar-ency of the metal films are characteristic of cathode rays as contrasted with light" "All substances obtainable in thin films proved to be more or less transparent." "Tissue paper placed on a phosphorescent screen" (Lenard's screen was composed of tissue paper soaked in pentadecylparatolylketone) "only cast a distinct shadow when in double layer". "Writing paper is already less transparent." Drawing paper .12mm.

·12 mm. thick had to be held quite close to "window" in order that "screen" behind it might glow perceptibly." Cardboard ·3 mm. thick intercepted all luminosity." Blown glass films ·02 mm. thick were equivalent nearly in transparency to drawing paper above mentioned; thinner they are more more transparent. Collodion films about ·01 mm. thick are transparent. Soap films cast shadows when thicker than ·0012 mm. Aluminium held close to window and ·027 mm. thick was just perceptibly transparent. Thin iron foil & ordinary tinfoil both ·02 mm. thick were equivalent in transparency to drawing paper above mentioned. In all cases the transparency or otherwise was tested by the use of the "phosphorescent screen" ~~of~~ glowing or remaining dark.

Lenard experimentally showed that "the atmosphere is a turbid medium for Cathode Rays; they are not propagated linearly but diffused."

"Cathode Rays are photographically active. Sensitive printing paper held near the window is blackened at about the same rate as by the subdued sunshine of a foggy day; behind a quartz plate it remains unaffected. Dry plates with development are perfectly & blackened at greater distances in a few seconds. The phosphorescent screen

may

may therefore be replaced by the photo-
-graphic plate. Fig.4. is the copy of an image thus obtained. In this case the sensitive lay-
-er was, as shown in fig. 4a, half covered with a quartz plate Q.Q. ½ mm. thick, across which was laid the double aluminium plate Al. If light had been the agent the appearance of the copy must have resembled fig. 4a. Fig.4 is very different from this. Not the aluminium plate, but the quartz plate has cast the black shadow. In the fourth quadrant this shadow is slightly altered, this is due to the light of the air; the effect is quite absent in the third quadrant which is covered both by quartz & aluminium. A very much stronger effect than that due to light is produced by the cathode rays, as shown in the upper half of fig. 4. A shadow of the double aluminium film is only faintly indicated in quadrant II. On the whole fig.4. is nothing but a faithful representation of the phenomena exhibited directly by a phosphorescent

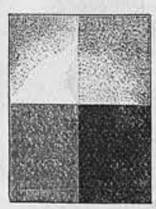


Fig. 4.

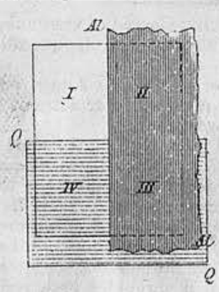


Fig 4a.

screen. But the photographic plate can bring to

II

to light effects otherwise imperceptible provided the exposure be long enough. Thus a pretty strong blackening was obtained behind the cardboard screen 3mm. thick described above as impervious. The cardboard covered the sensitive layer and strips of different metals were introduced between both. These strips appeared quite in accordance with their degree of transparency (in the negative) lighter on a dark ground, and the film only remained perfectly light when a thick metal frame was laid over all. So Cathode Rays had actually penetrated the thick cardboard. Exposure was only two minutes."

"A delicate thermometer and a thermopile placed at the "window" gave .. no definite indications of heat."

"Cathode rays penetrate into the interior of spaces closed metallically; they are perfectly divisible from the electric forces producing them."

"Electrified bodies lose their charges in the observing space."

Lenard now substituted in the observing space for ordinary air a long tube (which could be exhausted at will or filled with different gases) closely abutting on the "window". As regards the discharge tube he found it impossible to produce Cathode Rays in a high "perfect" vacuum. As regards the "observing space" he found that the higher the vacuum, the

more

more nearly did the rays become rectilinear, the farther were they propagated "nearly without loss of intensity". We see therefore that cathode rays are also propagated in spaces which only contain matter in those states of extreme tenuity in which all its known effects vanish. Not to the trace of matter ... but to the Ether alone, which we are not able to banish from any space must be therefore ascribe the causation of the intense effects observed. If this be granted our experiment concerning the nature of the rays will decide in favor of their being occurrences in the Ether."

"The permeability of different gases for Cathode Rays is very different; it shows a connection with the densities of the gases." "With increasing exhaustion the transparency of the gases increases; with great exhaustion the differences between the gases vanish." Lenard obtained fluorescence of a "screen" in a vacuum in the "observing space" of (.0083 mm mercury pressure) at a distance of 133 c.m. from the "window", even after shielding his screen with films of aluminium amounting to a thickness of .0133 mm — compare with 2.35 c.m. length from the "window" in air at ordinary atmospheric pressure. "Different gases are turbid media to very different degrees." "The turbidity is only determined by the density of the gaseous medium."

"Cathode

III.

"Cathode Rays of various kinds are diffused to different extents." Lenard considered he produced ~~the~~ different kinds of rays by varying the pressure in the discharge tube. "Rays produced at lesser exhaustions are more diffused than those produced at greater exhaustions. That there are different kinds of Cathode Rays .... which differ in the capacity of phosphorescence, absorption, or deflection by a magnet has already been remarked by Hertz." (Wiedemann's Annalen 19. p. 816. 1883)

III. In a further paper by Lenard ("On the Magnetic Deflection of Cathode Rays."

II

Rays" (Wiedemann's Annalen Vol LII. No 5. p. 27. translated in the Electrician May 25. 94. p. 108) "When Cathode Rays traverse a magnetic field their otherwise rectilinear path becomes in general curved, they are deflected by the magnet ... In the discharge tube ... the deflection increases with increasing pressure of gas. In this respect the behaviour of cathode rays agrees with that of small negatively charged particles projected from the cathode .... This agreement between Cathode rays and radiant matter .... can in reality be only superficial if the conclusion arrived at in my earlier Paper, namely that Cathode Rays are phenomena in the Ether, be correct. That the resemblance is only superficial in reality seems to me to be proved by the following experiments in which the agreement completely fails in this respect that conditions which must have the greatest influence on the speed of radiant matter appear quite without effect on the amount of deflection of cathode rays in a magnetic field. The experiments show that the amount of magnetic de-flection is not in the least affected by the medium in which the rays are "observed", that on the contrary the capacity for deflection of one & the same kind of cathode ray remains always materially the same in all gases at all pressures, with every intensity of ray, and even

even when the rays have to traverse a metal partition placed in their path; on the other hand, that in gases at different pressures different kinds of cathode rays are "produced", possessing different capacities for deflection." The experiments are then detailed. "Now there appears yet another kind of difference in these two kinds of rays; the former rays" (i.e. rays produced at smaller degrees of vacuum)" are more deflected by the magnet than the latter" (i.e. rays produced at smaller pressures). The deflection of the rays measured in the observing space does not depend on the pressure of the gas there, but on the pressure of the gas in the ~~observing~~ "discharge" tube. "The more deflectible ~~Finally he says~~ cathode rays have more diffusion in gases than the less deflectible". Finally he says "The deflection of the Cathode Rays is, according to Hertz's experiments, not an action of the magnet on the rays themselves, but an action of the magnet on the medium traversed by the rays.... For if forces worked between the magnet and the rays themselves, then the magnet itself if made movable would be deflected by the rays, which is not the case (Hertz, Wiedemann's Annalen 19 pp. 799 & 805, 1883) But the medium whose magnetic alteration is shown by the curvature of the rays, is according to our experiments, the ether itself. For the curvature was found to be completely independent of the nature and density of any ponderable medium which chanced to be present & was especially to be seen in the highest attainable vacuum" i.e. of the observing space.

IV

IV Prof. Wilhelm Konrad Röntgen's well known paper "On a New Form of Radiation" dated Dec. 1895. (Preliminary Communication to the Würzburg Physico Medical Society, translated in the "Electrician" Jan 24. 1896 p. 415 & in other technical publications). has now to be considered briefly in comparison with Lenard's results already quoted. From a vacuum tube covered with black cardboard & excited by a Ruhmkorff coil, Röntgen got a barium platinocyanide screen to fluoresce at a distance of 2 metres from the tube. The cardboard cover of the tube was opaque to ultraviolet rays of sun & electric arc. He found all bodies transparent to this agency from the tube but in very different degrees. Paper was very transparent; the screen fluoresced behind a volume of 1000 pages, & two packs of cards. Tinfoil needed to be in several layers to give a shadow. Thick blocks of wood are transparent. A film of aluminium 15 mm. did not entirely destroy the fluorescence of a screen. Several centimetres of vulcanised indiarubber let rays through; glass plates of same thickness behave similarly, but flint glass (containing lead) was much less transparent than other kinds. "If the hand is held between the discharge tube & the screen, the dark shadow of the bones is visible within the slightly dark shadow of the hand." Water and other liquids are very transparent. Plates of copper, silver, lead,

lead, gold, platinum if not too thick allow visible fluorescence. Platinum ·2 mm. thick is transparent. Lead 1.5 mm. thick is as good as opaque. Very similar to metals are their salts solid or in solution. To observe the presence of fluorescence the room must be completely dark. He concludes "that the transparency of different substances of the same thickness is mainly conditioned by their density". "With increasing thickness all bodies become less transparent". Other bodies fluoresce besides barium platino-cyanide – e.g. phosphorus, calcium compounds, ordinary glass. "Photographic dry plates show themselves susceptible to x-rays" (i.e. x-rays are used for brevity to indicate the radiations from the discharge tube producing the phenomena now in question). As these rays traverse thin sheets of wood, paper or tinfoil, we can study the behaviour of photographic plates to them in an ordinary well lit room. "In former days this property of the rays only showed itself in the necessity under which we lay of not keeping undeveloped plates, wrapped in the usual paper & board, for any length of time in the vicinity of discharge tubes. It is still open to question whether the chemical effect on the silver salts of photographic plates is exercised directly by the X rays. It is possible that this effect is due to the fluorescent light which, as mentioned above, may be generated in the glass plate or perhaps on the layer of gelatin. "Films may be used just as well as glass plates."

"The retina of the eye is not sensitive to these rays ~~at all~~ . . . . According to experiments made the media contained in the eye are fairly transparent".

Using prisms Röntgen could not detect any refraction of these rays, except doubtfully when using prisms of 30° angle of aluminium & vulcanised india rubber. Denser metals in prism gave no result on account of their want of transparency to x rays. "Powdered substances are quite as transparent to X rays as are solid bodies of equal mass. Hence it is proved that refraction and regular reflection do not exist to a noticeable degree." Hence X rays cannot be concentrated by lenses. Röntgen believes that regular reflection does not exist but that in an experiment he details ~~of~~ bodies like coins behave to x-rays as muddy media do to light. He concluded that x rays went through all bodies at the same speed "in a medium which is everywhere in which the material particles are embedded; the particles obstructing the propagation of the X rays in proportion to the density of the bodies".

Experiments with quartz & Iceland spar gave negative results as regards polarisation

Röntgen speaking of Lenard's conclusion about Cathode Rays that these rays are actions in the ether & that they pass diffusively through all bodies

bodies, says he can say the same about his rays. Photometrically comparing the intensity of screen fluorescence at different distances from the vacuum tube, he found it to vary inversely as the square of the distance from the tube. "Air absorbs a very much smaller fraction of the X-rays than of the cathode rays".

Röntgen says "I have not succeeded, even with very strong magnetic fields, in deflecting X-rays by a magnet". "It is certain that the spot on the wall of the discharge apparatus which fluoresces most decidedly must be regarded as the principal point of the Radiation of X-rays in all directions". This is supposed to be the point where the cathode rays impinge on the glass. "If one deflects the cathode rays within the apparatus by a magnet, it is found that the X-rays are emitted from another spot – that is to say, from the new termination of the cathode stream" "I therefore came to the conclusion that the X-rays are not identical with the cathode rays, but that they are generated by the cathode rays at the glass wall of the discharge apparatus".

After mentioning photographs he had taken including one of bones of the hand of objects enclosed in boxes, he says he was able

"Researches to investigate whether electrostatic forces act on the x-rays are begun but not yet concluded" able to take a pin hole photograph of the discharge apparatus in its opaque mantle. "The image is weak but unmistakeably correct"*.

Interference phenomena were looked for carefully without success. If of the nature of Ultra-violet light, then the x rays behave quite differently to all known infra-red, visible, & ultra-violet light as above detailed. "May not the new rays be due to longitudinal vibrations in the Ether? I must admit that I have put more & more faith in this idea in the course of my research."

V <u>Lenard's Cathode Rays compared with Roentgen's X-rays.</u>

<u>Differences</u>.

	Cathode Rays.	X-rays.
a)	Markedly deflected by a magnet.	Not deflected by a magnet.

Röentgen's observations on the use of a magnet being ineffectual in deflecting his x rays is experimentally corroborated by Prof. Oliver Lodge ("On the Present Hypotheses concerning the nature of Röntgen's Rays." The "Electrician" Feb. 7. 1896. (p. 471).

	Cathode Rays.	X-rays.
b)	Undergo much absorption and diffusion	Undergo much less absorption & diffusion

Compare the fact that the former failed to pass through anything except in the thinnest films

V

films, while the latter effectively traverse several centimeters of wood & several millimeters of metal or glass. The former are wiped out as regards inducing fluorescence 6 c.m. or 8 c.m. away from the "window" in Hydrogen gas at (.0146 mm. mercury pressure) their radiation length was only 130 c.m.; the latter act on the fluorescent screen at a distance of 2 meters from the discharge tube in air at ordinary pressure.

c. {Radiate from Cathode.} {Radiate from the luminescent spot where the Cathode Rays impinge on glass wall of vacuum tube.}

Resemblances. Cathode Rays and X Rays resemble each other in their action on the fluorescent screen & the photographic plate; in their linear propagation & projection of sharp shadows, on screen & plate, of bodies opaque to them; in their passage through bodies (this being conditioned mainly by density). Neither class of ray produces sensation on the retina of man.

It has been suggested that Röntgen's x-rays are the least diffusible & least deflectible Cathode Rays produced under favorable cir-
-cumstances

-cumstances as yet not definitely known. There is here a large field for experimental elucid-ation; and it may be noticed in this connection that Röntgen's is a preliminary communication in which he gives the general results but not the details of his researches as Lenard has done.

VI Physical nature of Lenard's & Röntgen's Rays.

Lenard (see II & III) regarded his rays as occurrences in the Ether. The resemblance under the action of the magnet of the behaviour of his rays in the discharge tube to what might be expected of small negatively charged particles projected from the cathode is "superficial". The deflection as observed in the "observing space" was more marked the higher the vacuum then & depended only on the initial deflectibility of the rays entering from the "discharge tube". As according to Hertz, the action of the magnet must be on the medium through which the rays passed & not on the rays themselves (because when left movable the magnet itself was left undeflected) and as the highest possible attenuation of ponderable matter in the course of the rays did not wipe out the phenomenon of deflection, this medium on which the magnet acted must be therefore (Lenard argued) the Ether itself.

itself". In opposition to this it may be pointed out on behalf of the supporters of the theory that Lenard's rays are due to action of residual matter that these rays might naturally be supposed to be extra rapid ultra-violet light but for the fact that there seems to be no reason to believe that light rays can be deflected by a magnet. At first sight there is no need to appeal to a new property of the Ether to explain the propagation of cathode rays when it is remembered that in Lenard's highest vacua there must still be 10^{10} molecules per mm. of residual matter. Even though Lenard lays stress on the fact that his vacua do not not sensibly deteriorate, we might imagine as many molecules being carried out as carried into the vacuum, or we might imagine some kind of electrolytic conduction from molecule to molecule, without any molecules streaming into vacuum at all. J.J. Thomson (On the Velocity of Cathode Rays" the "Electrician", Oct. 5. 1894 (p. 672) has experimentally measured the velocity of cathode rays in the discharge tube & found it to be "1.9×10^7 cm/sec." He says the action of a magnetic force in deflecting these rays shows, assuming that the deflection is due to the action of a magnet on a moving electrified body, that the velocity of the atom must be at least of the order we have found".

Röntgen

(See also "Note on the memoir of Herr Jaumann entitled "Longitudinal Light" H. Poincaré "Comptes Rendus" No 23 1895, translated in the "Electrician" Jan 31, 1896 (p. 453) and "Cathode Rays" by G. Jaumann "Comptes Rendus" vol CXXII No 2. translated in the "Electrician" Feb. 7 1896 p. 457.)

Röntgen says (see V) "may not the new-rays" (i.e. his x-rays) "be due to longitudinal vibrations in the Ether?" The mathematical elements of such a theory have been worked out by G. Jaumann ("Longitudinal Light", Wiedemann's Annalen 57. 1 p.p. 147 — 184, 1896; translated in the "Electrician" March 6, 13, & 20 1896 at pp. 629, 656, & 685 respectively) Some experimental evidence in support of the Ethereal theory of Lenard's rays is given by J. Elster & H. Geitel ("On the Motion of the Luminous Glow in Rarefied Gases produced by Electric Oscillation" Wiedemann's Annalen, Vol LVI No. 12. p. 133, translated in the "Electrician" Jan. 17. 1896 p. 387); & against it by Jean Perrin ("New Properties of Cathode Rays" Comptes Rendus Vol. CXXI No 27. p. 1130, translated in the "Electrician" Feb. 14. 1896 p. 523). The absence of observed deflection of Röntgen's rays puts out of court the theory of ~~[illegible]~~ electrically charged particles at high velocity producing his phenomena. Prof. Lodge, in confirming Röntgen's non-observance of deflection of his rays in the magnetic field points out "the investigation into this matter is not finished until a further experiment is done — viz. to verify the non-deflectibility of the Röntgen rays even in a fairly good vacuum." ("On the present hypotheses concerning the nature of Röntgen's Rays", the "Electrician" Feb. 7. 1896

1896 (p. 471) In the same paper Prof. Lodge points out that the transparency of electrical conductors to x rays is contrary to the opacity they present to Light – "to light of every kind they ought to be opaque". To get over the difficulty the waves must be supposed to be much smaller than anything hitherto known & to compare closely in size with the atoms themselves. Last of all comes the theory that the x rays are longitudinal or "sound" waves in the ether. "Assuming wave propagation of some kind, every argument against transverse is in favour of longitudinal" "Now the thing that suggested longitudinal waves to Röntgen was the fact that crystalline properties were of no importance – that Iceland spar & quartz were equally transparent or opaque whichever way you turn them. .... If tourmaline is transparent to Röntgen rays going along its axis it would be a much better test; & this I have myself ascertained to be the case. J.J. Thomson has also found that a pair of ordinary cut tourmalines are equally transparent whether their axes are "crossed" or parallel... nothing suggestive of polarisation ~~has~~ in any form has yet been observed; a fact which tends against transverse & in favour of longitudinal waves. But the strongest argument in favour of longitudinal rays is derivable from the fact that the rays discharge electrified bodies. Lenard found this, & J.J. Thomson and I have both obtained it easily under Röntgen-like conditions.

""On the Generation of Longitudinal Waves in the Ether" Lord Kelvin. (The "Electrician." Feb. 28. 1896 (p. 593)

Also extract from Prof. Boltzmann's paper in the "Zeitschrift für Elektrotechnik" Jan 15 1896 (quoted in the "Electrician" Jan. 31. 1896 p. 447) conditions; but their peculiarity is that (unlike Light) they discharge positive & negative about equally."

In additions to papers already referred to under present head (VI), the following may be noted:—

"On Cathode Rays in Gases under Atmospheric Pressure & in Extreme Vacua" Prof. G. F. Fitzgerald. (The "Electrician" March 23, 1894, (p. 573.)

"On Herr Lenard's experiments on the magnetic action of Cathode Rays." ditto (The "Electrician" June 8, 1894 (p. 151)

"On the Rays of Lenard & Röntgen" Dr Oliver Lodge (The "Electrician" Jan. 31. 1896 (p. 438).

VII ☞ Subsequent History and Applications of Röntgen's discoveries

Subsequent to the publication of Röntgen's paper, the use of his rays to produce shadows of objects, otherwise invisible, on the photographic plate & the fluorescent screen has employed the attention of many workers. Very little has been done to supplement, much has been done to verify, & nothing has been done to contradict his conclusions. Many results have been announced as novelties which are to be found in his very comprehensive paper set forth at length; and some improvements have been actually achieved to shorten the time of exposure of the photographic plate

plate. Many names have been suggested for the actual process (with corresponding terms for the resulting image or print in most cases) e.g. 'Shadowgraph' & 'Shadowgram'; these though fairly descriptive are somewhat vague & besides are barbarous. 'Scioscopy' & 'Sciagraphy' are exceedingly good as distinguishing the use of the screen & plate respectively, but the former is already used to signify **the shadow test in examining** into the refraction of the eye. Sciagraphy has also been proposed. 'Kathodography' 'Actinography' & 'Electrography' are all objectionable as applied to the quite peculiar properties of x-rays. 'Röntgenography' & 'Röntgenotype' are cumbrous as well as barbarism (the latter like 'Daguerreotype'). The least objectionable & most definitely distinctive titles are those of 'Radiography' & 'Radiogram', which seem more & more coming into general use; in addition to which if necessary the term 'Radioscopy' might be suggested to apply to the use of the screen. As this dissertation means more than a mere description of the process of photographing a shadow cast by means of Röntgen's rays, I have adopted in the title the periphrasis "Radiographic Projection".

The further history of the discovery is most conveniently considered under the following heads:-

<u>Empirical</u> <u>Research</u>. a.

a. Physical Research.

Experimental Work by J.J. Thomson, Elster & Geitel, Perrin, Lodge & J.J. Thomson has already been referred to under VI.

Much additional work ~~has been done~~ in investigating the effects of Cathode & x rays on electrified bodies has been done; but the results of different observers are somewhat contradictory. J.J. Thomson (letter to the "Electrician" Feb. 7. 1896 p. 491) finds that a charged insulated plate exposed to Röntgen's rays rapidly loses its charge. – positive as well as negative, and the leakage goes on when the electrified plate is embedded in paraffin, ebonite, mica, sulphur. "This shows that all substances through which the Röntgen rays are passing become for the time conductors of electricity". Prof. Borgman of St. Petersburg (the "Electrician" Feb. 14. 1896 (p 501) says "Röntgen rays discharge rapidly positive electricity, slower negative. At short distances they give negative electrification. They increase spark gap. Aluminium sheet does not hinder interaction". L. Benoist & D. Hurmuzescu ("new properties of the x-rays "Comptes Rendus" Jan 27. 96. p. 235 translated in the "Electrician" Feb. 14. 1896) found that x rays immediately & completely discharged the electroscope, though more rapidly in the case of negative charges than in the case of positive. Prof. Righi "On the production of Electric Phenomena by means of Röntgen's Rays" a proceeding of Royal Academy of Science of Bologna the Electrician Feb. 21. 1896 (p. 552) finds that both negatively & positively charged

MM. Benoist & Hurmuzescu can find no trace of electrification by x-rays, but have alighted on similar phenomena to those described by Minchin. ("Comptes Rendus" March 30. 1896 in the "Electrician" April 10. 1896 p. 782.). After giving their results for different substances they conclude "Hence the aptitude with which the different metals utilise the energy of the X rays to dissipate electricity clearly varies inversely as their transparency for these rays."

Mr. James R. E. Murray ("On the effect of the Röntgen x-rays on the contact electricity of metals" the "Electrician" April 24. 1896) finds (1) that the influence of the rays on the zinc & tinfoil plates used in his experiments does not cause any direct or sudden change in their contact potential but that (2) the air through which the rays passed is temporarily converted into an electrolyte and forms a connection between the plates as a drop of acidulated water would do.

charged bodies are dis-electrified by x-rays; he has also observed their electrifying power, but this is negative. C. J. S. Carr (letter to the "Electrician" Feb 21 1896 (p. 559) finds x-rays to increase sparking. G. M. Minchin (letter to the "Electrician" March 27 1896 p. 737) finds "the X-rays charge some bodies positively and some bodies negatively, and whatever charge a body may receive by other means, the x-rays change it both in magnitude & sign to the charge which they independently give to the body"; he gives a positive & a negative list. See also notice in the "Electrician" April 3 1896 p. 750 of a paper by J. J. Thomson & J. A. McClelland "The Leakage of Electricity through Dielectrics traversed by Röntgen's rays". It will be interesting to read Röntgen's own papers on the matter. see section IX.

In Lodge's paper in the "Electrician" Feb. 7. 96 p. 473 it is stated "J. J. Thomson has exposed a protected photographic plate inside the vacuum" (i.e. of discharge tube) "& got no result". In "Comptes Rendus" Feb. 17. 1896 (the "Electrician" March 13. 1896 p. 646) Auguste & L. Lumière found ten minutes exposure to x-rays produced a photographic effect through 250 sheets gelatino-bromide-silver paper; 300 sheets of paper without the bromide emulsion exercised the same absorptive effect as 150 sheets of sensitized paper; they found photographic plates differing in sensitiveness to *ordinary light in the ratio of 1.8 to 30, & showed the same difference in sensitiveness to X. rays. Prof.

Prof. Sylvanus Thomson ("Comptes Rendus" Vol CXXII
Quoted in the "Electrician" April 24. 1896 p. 866.
No. 14. p. 809.) says "By means of the fluorescent screen we are also able to show the heterogeneity of the x-rays. With moderate vacua the x-rays do not penetrate the flesh to the exclusion of the bones as completely as when the exhaustion is carried further. On the other hand when exhaustion is carried very far, the x-rays penetrate not only flesh, but bone also. Hence there is a certain degree of exhaustion for which the difference in the transparency of flesh & bone is a maximum."

Prof. Dewar from a large number of experiments ( ) argues that opacity to x-rays increases with atomic weight, not with density merely. Messrs Ackroyd & Knowles (Physical Society, March 13. 1896) have exposed a number of pieces of metal, oxides, & sulphates to x rays & found in each case the opacity increased with the molecular weight.

L. Benoist & D. Hurmuzescu find x-rays to be heterogeneous ("Comptes Rendus" Feb. 17. 1896. in the "Electrician" March 13. 96. p. 646).

Abel Buguet & A. Gascard ("Comptes Rendus" Feb 17. 1896 in the "Electrician" March 13. 96 p. 646) find natural diamond & jet more transparent than the artificial. Bunsen's flame is transparent (C. E. S. Phillips – letter to the "Electrician" Feb. 21. 1896. p. 559.)

Lodge ("Further progress in Radiography" the "Electrician" April 10. 1896 pp. 783-4) has experimentally investigated the source of the x-rays in the vacuum (discharge) tube. He finds that when the rays from the cathode impinge first on a glass surface, then that surface is the source, every point of it radiating independently like a hot surface. But when the cathode rays first strike a piece of metal enclosed in the bulb, the behaviour of the piece of metal struck depends on what it is connected to — if the bombarded piece of metal is attached to the cathode in such a way that it cannot receive any electrical charge from

from the cathode stream, then it either declines to act as an emitter of x-rays or else emits them of the feeblest kind; but if the bombarded disc be connected to the anode so as to be able to receive the negative charges of the cathode stream, then it acts as a most vigorous source of x-rays, & in a high vacuum it keeps cool & the whole energy supplied seems to pass off as x rays. Lodge's experiments were made by producing pinhole photographs of the discharge tube in action & comparing them with pencil tracings of the visible phenomena on a glass screen.

B. Physiological Research.

A few Physiological (or rather Pathological) Researches have been made by means of the x rays.
Profs. Kirmen & Waymouth Reid have tested the relative transparency of various tissues of the cat, 3 mm. thick. Bone was most, & cartilage least opaque. Next to cartilage in transparency was fat. In the kidney the cortex was far more transparent than the medulla. In both cerebrum & cerebellum the white matter was more transparent than the grey. An experiment with a slice of cancerous human liver showed no difference in transparency of the cancerous & of the normal parts. ("British Medical Journal". Feb. 15. 1896 p. 433).
Prof. Schuster & Sheridan Delépine have published some experiments of the action of x-rays upon bacteria. Nine tubes containing recent cultures of cholera vibrio, bacillus coli communis, & bacillus of enteritis were exposed to the rays for 15 min., for 30 minutes, & for 1 hour. Control tubes were kept under same conditions without exposure to the rays. From each tube ~~[illegible]~~ inoculations were made into bouillon & nutrient gelatine. No difference could be detected between the growth of organisms exposed & unexposed to the x rays. A new set of tubes were experimented on containing bacillus anthracis, bacillus of enteritis & cholera vibrio & inoculation was made on nutrient gelatine. An exposure of 75 minutes, followed after an interval by re-
- exposure

exposure for 45 minutes had no effect on the growth of the latter. ("British Medical Journal" Feb. 29. 1896).

Mr. Gifford of Elland has found that cotton wool saturated with chloroform is opaque, whereas cotton wool itself is transparent. ("Photography" March 5. 1896 (p. 163)

Dariex & De Rochas experimenting on the eyes of freshly killed frogs find that the media of the eye are but slightly transparent to X-rays. ("Comptes Rendus" Feb. 21. 96 in the "Electrician" March 13. 1896 p. 646).

Prof. Neusser finds phosphatic calculi quite opaque, cholesterine gall stones rather less so ("British Medical Journal Feb. 8. 1896 p. 362.) J. T. Leon publishes (in "British Medical Journal" for April 4. 1896 p. 875) a radiograph showing relative opacity of a coin, a finger, biliary concretions, gall stones, oxalate of lime, phosphate of lime, triple phosphate & uric acid — the last of course are urinary calculi. The calculi were nearly of same thickness as the coin and was most transparent.

Pinard ("Bulletin de l'Acad. de Méd." No 10. 1896 in British Medical Journal's Epitome of Current Medical Literature for April 18. 1896 p. 62) radiographed a dead foetus in utero 55 minutes i.e. a specimen in uterus removed post mortem.

c. Clinical & Diagnostic applications:

3. Clinical & Diagnostic Applications.

(It is proposed to notice only the most important or the earliest of each kind.)

Prof. Mosetig's two cases. The first was a case of double distal phalanx of hallux, when the photograph enabled operator to fix on the phalanx that was supernumerary to the normal one; the other was a case of bullet in fourth interosseous space of right metacarpus. Both radiograms are published in "British Medical Journal" for Feb. 8. 1896 p. 363.

Haschek's & Lindenthal's experiments. ("Wien. Klin. Wochenschrift", Jan 23. 1896 in "British Medical Journal" Feb. 8. 96.) photographed a child's arm, forearm & foot. On a dead hand after injection they were able to photograph the blood vessels.

Lannelongue's case of Osteomyelitis of femur when photographed showed that destruction of osseous tissue was from within outwards. ("British Medical Journal" Feb. 8. 1896)

Sidney Rowland shows a case of deformity of foot from tight boots with radiogram (in "British Medical Journal of Feb. 15. 1896.) ~~In~~ Mentions a fracture of the forearm photographed by Prof. Röntgen on Jan 25 and a negative of a bullet in carpus photographed by Prof. Lodge. Both radiograms are published in "British Medical Journal" for Feb. 22. 1896 p. 493 & 494.

In the "British Medical Journal" for Feb. 22. 1896 p. 493 is a case of osteoarthritis of hand radiographed; & also radiographs of kidney & hand injected with red lead

mass

VII C.

ness of the dissecting-room.

It is impossible to say exactly who first radiographed a needle in hand or foot or when it was done, but it seems to have been the experiment most early, most often, and most successfully tried.

Sydney Rowland reports taking a radiograph of suspected tubercular disease of foot ("British Medical Journal" Feb. 29. 1896 p. 557).

Sidney Rowland reports, with publication of radiograms, a case of dislocation of elbow—both bones outward—where great swelling existed ("British Medical Journal" March 7. 1896 p. 620); also a case of dorsal dislocation of terminal phalanx of finger (p. 621). He also reports an attempt to radiograph through the larynx and succeeded in taking on a sensitive plate on one side of larynx a pencil nail and a fish bone attached to skin by sticking plaster on the other side. The larynx with exception of hyoid cartilage is so very transparent, that to aid in locating a foreign body there, the aid of a chart already drawn would be necessary. He also reports an attempt to radiograph in a case where diagnosis lay between malignant hepatic disease and impacted gall stones. He was unsuccessful in diagnosing an opaque mass, but got the x-rays through full thickness of the body. He also ~~the~~ radiographed a sarcoma of tibia from which it appeared that the tumor arose inside bone and expanded it. ("British Medical Journal" March 14. 1896 p. 683).

It

It is reported (in "Photography" March 19. 1896 p. 199) that Dr. <u>Hall Edwards</u> of Birmingham had radiographed the backbone in a living adult.

<u>Sidney Rowland</u> (in British Medical Journal March 28. 1896 p. 807) publishes a radiogram of a child three months old – the exposure was 14 minutes & the distance of plate from tube 8 inches. The heart & lungs are clearly silhouetted & the coils of the intestines. In same page he also reports radiographing a halfpenny swallowed some months before which was shown over right iliac bone having evidently caught up at the ileo-cecal valve. The child was six years old & the negative "showed" pelvis vertebral column and lower parts of thorax". Mr. Rowland does not say whether these cases ~~were~~ alive or not. In regard to the radiograph published of the first case of the ~~1~~ 3 months child, the remark at once suggests itself that the child must have kept remarkably still.

<u>Prof. Lodge</u> ("Further Progress in Radiography" the "Electrician" April 10. 1896. (p. 783) reports he has radiographed a "Murphy's Button" inside an adult with an exposure of 10 minutes. The patient was alive.

<u>Sidney Rowland</u> ("British Medical Journal" April 11. 1896 (p. 923) gives a very interesting list of work done, published & unpublished, by him. The list includes foreign bodies, diseases & deformities of extremities, fractures, dislocations,

dislocations of extremities, the method seems of special value in obscure affections of joints. With the aid of a cryptoscope he was able to see a sound passed into larynx ("British Medical Journal" April 18. 1896 p. 997)

E. B. Davis ("American Journal of Medical Science", March 1896 in "British Medical Journal's Epitome of Current Medical Literature for April 18. 1896 p. 62) reports radiographing an 8½ months foetus in utero, in living parent. He got a faint outline of foetus with 75 minutes exposure.

Mr. Sydney Rowland's best results are a case of 'suspected Calcified Glands' in a Child, a case of Fracture into knee joint, four cases of 'Excision of the knee joint' & one of 'Excision of the Elbow', & a case of 'Multiple Exostoses' in a child of 9 years age, two 'skiagraphs' of which last are published in the "British Medical Journal" (April 25 1896 p. 1059 - 1061).

Prof. Huber ("Deutsche med. Woch." in Epitome of Current Medical Literature" of "British Medical Journal" April 25. 1896 p. 65) has applied radiography in the diagnosis of rheumatic gouty affections. Details are given of five cases.

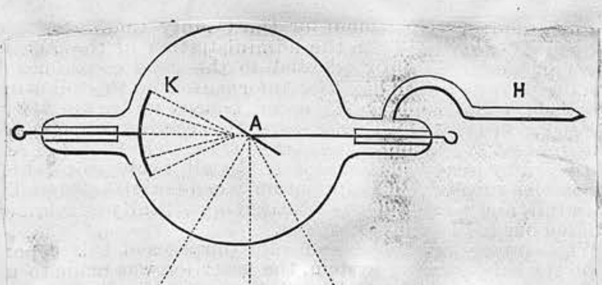
8. Improvements suggested in Apparatus.

D. Improvements Suggested in Apparatus.

These may be noted conveniently under four heads:— Electric Apparatus, Vacuum Tube, Screen or Cryptoscope, and Photographic Dry Plate. The two first produce, the two last render ~~two~~ visible, the Rays; the screen or cryptoscope temporarily, the plate permanently.

Electric Apparatus. Various combinations of primary current (town mains suitably arranged, hand dynamos, Wimshurst influence machine, or a make and break galvanic battery) with intensifying arrangement (large Ruhmkorff or Apps coil with or without Leyden jars or other condenser, or a coil whose secondary is made the primary of a Tesla oil coil), have been used by successful radiographers. Thus Mr. G. Clifford Beard used a coil worked by a hand dynamo, Mr. A. A. Campbell Swinton an alternating current of 20,000 volts pressure which excited a coil the secondary of which charged a battery of 12 half gallon Leyden jars, the discharge from which ran into a second Tesla coil & thence to the vacuum tube. ("New Light" 2nd edition p.p. 150 & 12 respectively).

Mr. Sidney Rowland used generally an ordinary induction coil without a Tesla coil. He recommends a battery of 6 or 8 Bunsen or Grove cells in series "Dry cells are of no use at all, & bichromate batteries fall off so rapidly that they are unsuitable for the long exposures sometimes necessary." ("British Medical Journal" Feb. 8. 1896)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1896). Röntgen used a Ruhmkorff coil simpliciter, all these workers got most excellent results with moderate times of exposure. When we consider the the great difference in frequency between the enormously rapid alternate currents from a Tesla apparatus as compared with the comparatively slow sparking at the electrodes of a secondary coil of the ordinary type, when also it must be remembered one of the sets of currents in one direction is damped down as compared with the other, it is necessary to remember that nothing is definitely certain about the conditions under which some workers obtain effective x rays where others fail.

For ordinary medical use the type of apparatus recommended is that consisting of a battery of 6-10 large 10 pint Bunsen & Grove cells, and a good coil throwing a spark of from 6 to 8 inches long.

Vacuum Tube. Various shapes & patterns have been suggested. The essential is a high vacuum, & that lead does not enter into the composition of the glass. The tube must be carefully insulated & thoroughly dry. When heating is apprehended, the primary current is turned off and on alternately for 15 secs. during the time of exposure.

Special notice must be taken of the "focus tube" which is diagrammatically represented on the opposite side. It was devised by Mr. Herbert Jackson on an old model of Crookes'. "The kathode plate K is a concave

II D.

concave disc of aluminium, which focuses the rays at a point near the centre of the bulb. The anode plate A is a small piece of platinum foil placed at an angle a short distance beyond the focus of the kathode rays. Curiously enough the cathode rays do not cross like rays of light at the focal point, but behave rather like a number of fluid jets colliding at the focal point, and proceeding thence onward as a solid parallel jet. The point where the rays impinge on the platinum still retains its small dimensions, though the plate is placed some distance behind the focal point. Platinum is known to be one of the most opaque substances for the cathode rays, and thus very little of the radiation passes through the platinum foil. The greatest part of the radiation is absorbed by the platinum and given out as x rays from the luminous point by a kind of diffuse ~~radiation~~ reflection. The anode plate A, being set at an angle, the best part of the radiation is directed downwards through the sides of the bulb, where it can be conveniently utilized to produce the photographs in the ordinary way. The tube H, through which the bulb is exhausted, is shaped so as to permit the tube to be fixed in a stand at the required height. The anode and the cathode are connected to the terminals of the induction coil by platinum wire fused through the glass" (Sydney Rowland "British Medical Journal March 21. 1896 p. 748.)

By

By the use of this tube the time of exposure has been much diminished. Some parts of the explanation given are somewhat questionable.

In reference to material, Prof. Lodge says "the phosphorescence of the glass bulb is handy as an index but has no further advantage..... The lighter and thinner the better one would suppose; and I doubt if very much advantage will be gained by replacing it by aluminium. I must say however that tungstate of calcium seems to me not only improper to so say, there a non-fluorescent substance, or a less fluorescent substance than glass, may be really better for the walls of the tube. I anticipate that the use of uranium or other such glass would be a step in the wrong direction." ("Further Advances in Radiography" "The Electrician" April 10. 1896 p. 784)

According to him the phenomenon of "fatigue" in tubes is due to the vacuum becoming too good under prolonged exposure, the residual molecules of the gas passing into the glass, from which they can be liberated by the flame of a Bunsen Burner.

Of the Aluminium tubes a promising form is that of Prof Woodward figured in the "Electrician" and described there.

Screen & Cryptoscope. The Cryptoscope, to which Salvioni's name is attached, is merely the

dark

dark room in which Röntgen observed fluorescence [illegible] for application to the eye. It may take the form of a light tight tube or box to which one or both eyes may be applied, with a "screen" at the far end shielded from adventitious light by cardboard. The distance of the "screen" from the eye should be that at which observer can read print in a dull light. Salvioni used a lens ~~tube~~ to observe with, but that is not necessary.

Roentgen used Barium platino cyanide as his fluorescing substance ($Ba\,Pt.Cy_4 + H_2O$). Potassium platinocyanide appears rather better ($K_2\,Pt.Cy_4 + 3H_2O$). Edison after trying a large number of substances advised the use of Tungstate of Calcium ($CaWO_4$), which is as good again and cheaper — he places it first, then comes tungstate of strontium, salicylate of ammonia and platinocyanide of barium (Telegram to Lord Kelvin in the "Electrician" March 20 1896 p. 703 see also "Photography" April 23. 1896 p. 278) according to him the tungstate of calcium must be "properly crystallised". On screens the difficulty seems to be to get an even uniform layer. The substances seem to be made up into pastes with gum & thickly spread over either the x-ray-opaque shield or over a glass backing; or the support is covered with varnish or gum & the fluorescent substance thickly

thickly deposited over.

Photographic Dry Plates. Reports seem to agree that the more rapid the plates & the thicker the layer of emulsion the more suitable the plate for radiographic use. Isochromatic plates except for their rapidity seem no special advantage. One well known maker of plates has put a special "cathodal" plate on the market, but no special principle is given as to its construction. Films are equally good to glass plates, & as the celluloid is extremely transparent to X-rays several radiograms can it is stated be taken simultaneously of the same object.

Experiments are being made as to the utility of mixing fluorescent substances with the sensitive emulsions, and as to placing screens impregnated with fluorescent substances in front or on back of sensitive plate. (Prof. Grinder of Bonn "Photography" Feb. 6. 1896 p. 91) (M. Henry "Comptes Rendus" Feb. 10th 1896 noted in the "Electrician" Feb. 21. 1896 p. 557).

Prof. Lodge says in his paper "Further Progress in Radiography" "If the films themselves can be made to fluoresce without otherwise being damaged, it may be a step in the right direction; but ..... a coating of fluorescent material near the film tends rather to a scattering and diffusion

diffusion of light—a poor exchange for the straightforward penetrating property of the x-rays themselves". Mr Campbell Swinton is more hopeful (letter to the "Electrician" April 24. 1896 (p. 866).

A Radiograph is not an image—it is a projection shadow—its analogue in real photography is the old talbotype, the imprint of ferns in a photographic printing frame upon a sensitive piece of fabric, a form of ornament still occasionally to be seen. No means has yet been discovered of refracting x rays by a lens to form an image, nor do they appear to be regularly reflected. It has been suggested however that a stereoscopic effect might be obtained, by repeating exposures of a given object with a relative displacement of the Crookes tube. We could thus get the true position of any foreign body in space. The prints thus obtained are mounted in a stereoscope. This has been done very successfully by Mr. Elihu Thomson & he proposes to apply his principle to the cryptoscope ("Stereoscopic Röntgen Pictures" the "Electrician" March 13. 1896. p. 661.).

VIII Some other forms of Energy which act on the "Dry-Plate".

Röntgen's discovery emphasises the fact, that besides being sensitive to the undulations of the visible spectrum and for some distance beyond it at either end, the "Dry-plate" of to-day is a very delicate instrument for registering otherwise insensible effects - partly because the silver-salt is in a state of unstable equilibrium & readily falls into the developable condition and partly because the time of exposure may be prolonged at will of the experimenter. Since the publication of his paper many strange affections of the photographic plate have been reported. Some reports undoubtedly suggest an imperfect use of the dark room and want of photographic cleanliness; but after excluding any errors of manipulation between the removal of the dry plate from its covering and the process of fixation, some well attested phenomena remain to be briefly noted here.

Inductograms. If the vacuum tube be dispensed with, and the sensitive plate with metallic design ~~resin~~ in contact be placed between ~~resin and~~ the terminals of the electric apparatus or in the neighbourhood of the sparking pole, Mr. Gifford found

The more accurate reference is "The Photography of metallic Objects through Opaque substances by means of the Brush Discharge of an Induction Coil without a Crookes Tube" (G. Moreau. "Comptes Rendus" Feb. 3. 1846 p.238 summarized in the "Electrician" Feb. 14. 1896 (p. 524).

he occasionally got a shadow of the discs. When two of the discs were adjacent he found lines like the impressions of spark discharges. In some cases he only got impressions as of brush like discharges. He used an Apps's coil. ("The New Light" 2nd Edition p. 14. being special issue of "The Photogram" Feb. 1896). Using a Rhumkorff coil in Paris similar results seem to have been got by M. <u>Moreau</u> (Communication by M. <u>Lippmann</u> to the Academy of Sciences Feb. 3. 1896 quoted in "Photography Feb. 6. 1896) Using a Tesla transformer, Mr <u>Sidney Rowland</u> got the images of coins in contact with a sensitive plate, not merely the shadow or outline but a print of the whole engraving on the near side of the coin, & this on whichever side of the plate the coin was put. ("British Medical Journal" Feb 9. 1896 p. 361 with prints of his results Feb. 16. 1896 p. 431). Of a similar nature appear to be <u>Lord Blythswood's</u> results ("The Electrician" Feb 14. 1896. p. 524 & Feb. 21. 1896. p. 559). He used a very powerful Wimshurst Influence-machine. Messrs. <u>Whitehouse & Segnitz's</u> results are also probably similar in nature ("Photography" March 5th 1896 p. 162) Mr. Segnitz got results by using an Electrophorus excited with cat's-skin.

These effects are all probably due to induced electricity in the metallic bodies affecting the sensitive plate in contact with them. They are not due to Lenard's or Röntgen's Rays.

<u>Thermographic Images</u> These are prints of coins slightly

slightly warmed placed on moistened dry plates. ("Thermographic Images" by C. S. Townsend in the "Photogram" April 1896 (p. 87).) Dr. Armaignac's results in printing from a negative by means of a petroleum lamp are probably due to radiant heat, a subject worked out in this country by Capt. Abney. The exposure was three hours. ("The British Medical Journal" Feb. 22 1896 (p. 142). Possibly his results may be explained under "Black Light".

The Arc Lamp. may influence the dry plate shielded from ordinary light. Schmidt of Munich found that light from an arc light of 43 ampere current affected a dry plate 16 inches from it in 10-12 seconds, through a wooden board 2 mm. thick. At same thickness india rubber, horn & ebonite proved less transparent, an exposure of half an hour being required to produce the same effect. ("Photographische Rundschau" No 1. 1896 quoted in the "Electrician" March 13. 1896 (p. 645).)

It is very doubtful whether this effect was due to anything analogous to Lenard's or Röntgen's rays or not.

Blende hexagonale artificielle or hexagonal Zinc sulphide acquires phosphorescence after a momentary exposure to sunlight. M. Troost states that this substance gives out rays which affect the photographic plate similarly to x-rays. Placed in a box it may be substituted for all the electrical apparatus of a Crookes tube. ("Photography"

March

For details as to the power of phosphorescent bodies to give off invisible rays which pass through opaque bodies after visible phosphorescence has ceased see "Comptes Rendus" March 2. 1896 No 9. paper by M. Henri Becquerel. also in the same for March 9. 1896. (Summarized in the "Electrician" March 20. 1896 p. 680.)

The lamp head of parabolic reflector.

March 19. 1896 p 200 and "British Medical Journal" March 20. 1896 p 748, where original references are given) In absence of details no comments are necessary.

"Black Light". A series of phenomena have been obtained during the last two years and described under this title by Mr. G. Le Bon. He took a plate of aluminium with figures in relief on one side. Against the other side he put a sensitive dry plate. He enclosed in a frame that let in no light & exposed to a paraffin lamp light for three hours. On developing the plate he got an image or print of the figures in relief, the thicker parts of the plate being more opaque than the thinner. He took a photographic negative & against it he put a sensitive plate, in front he put an iron plate; he then enclosed in a frame & exposed to lamp light as before. After three hours he developed the plate, & after pushing development he got a faint but recognisable positive print of his negative. He was successful with daylight. Even two experimenters have succeeded in obtaining same result, others have failed. Sunlight also produced these effects. He was able to exclude heat or fluorescence as a cause, & is experimenting to see whether electricity may not have something to do with it. He believes his "rays" are intermediate in nature

VIII

nature between waves of light and waves of electric-
-ity. He finds cardboard and black paper
such as are used in wrapping for dry plates
opaque to his "rays", & points out that in this
they are totally different from Lenard's &
Röntgen's rays (see note from M. Gustave
Le Bon on p. 14. of "New Light" special issue 6th ed.
of the "Photogram" for Feb. 1896; also "Dark Light"
by M. Le Bon in the Photogram for March 1896
p. 77; also his "Nature & Properties of Black
Light" the "Photogram" for April. 1896 p. 93).

X In a second communication ("On a New Form of Radiation", the "Electrician" April 24. 1896 p. 850) Prof. Röntgen gives some new results. He says that at time of his first communication (already summarised) he was aware that x-rays discharged electrified bodies. "I suspected it was x-rays, not the unaltered cathode-rays .... that Lenard had to do with in connection with distant electrified bodies." To protect his observations against influences of an electric nature from vacuum tube, coils and wires, Röntgen got into an airtight box, lined with lead opposite the source of the x rays, and covered elsewhere with zinc except on the side near the discharge apparatus, where a slot was made 4 cm wide "hermetically closed with a thin aluminium sheet". Through this slot the x rays would enter the observation box. He found (a) "Positively and negatively electrified bodies in air are discharged when placed in the path of x rays, the more quickly the more powerful the rays." It did not matter whether the bodies were conductors or insulators. He discovered "no specific difference in the behaviour of different bodies with regard to the rate of discharge" or "to the behaviour of positive and negative electricity". (b) "If ~~the~~ an electric conductor is surrounded by a solid insulator, such as paraffin, instead of air, the radiation acts as if the insulating envelope were swept by a flame connected to earth".

(c)

IX

(c) If this insulating envelope is closely surrounded by a conductor connected to earth, which should like the insulator be transparent to x-rays, the radiation .... apparently no longer acts on the inner electrified ~~body~~ conductor". (d) These observations tend to show that "air traversed by x-rays possesses the property of discharging electrified bodies with which it comes in contact." (e) If so "if the air retains this property for some time after the x rays have been extinguished, it must be possible to discharge electrified bodies by such air, although the bodies themselves are not in the path of the rays." By means of an aspirator he drew air which had been played on by X-rays past an electrified insulated body in the protected part of his observing box – i.e. behind the lead away from the slot. The charge of the insulated electrified body at once diminished considerably as measured by a Hankel electroscope. If the electrified body was kept at a constant potential by accumulators, an electric current was started as if the insulated body had been connected to the rest of the apparatus by a bad conductor. (f) How does the air lose this property? "Whether it loses it, as time goes on, without coming into contact with other bodies is still doubtful. It is quite certain, on the other hand, that a short disturbance of the air by a body of large surface, which need not be electrified, can

can render the air inoperative." He used a plug of cotton wool, & found that if air had to stream through this after being influenced by x-rays, the electrified insulated body no longer lost its charge. Several layers of small meshed wire gauze acted in same way. (g) Electrified bodies in dry Hydrogen are discharged equally well, perhaps more slowly. (h) In highly exhausted vessels the discharge of a body in the path of the x rays is much more slow than in air or hydrogen at atmospheric pressure. (i) Experiments with a mixture of hydrogen & chlorine have been commenced. (j) "Results of the investigations on the discharging property of the x-rays, in which the influence of the surrounding gases was not taken into account, should for the most part be accepted with reserve".

As regards apparatus used to electrify ~~[illegible] so~~ the vacuum tube Röntgen found it of use to put in circuit between the tube and the coil a Tesla condenser & transformer. The following advantages were obtained (1) the apparatus gets less hot & there is less probability of its being pierced; (2) the vacuum lasts longer; (3) the x-rays are stronger. "The question now arises .... whether it be possible to generate x-rays by means of a continuous discharge at a constant discharge potential, or whether oscillations of the potential are invariably necessary for their production.

" no

"No solid bodies" are "incapable of generating x-rays under the influence of cathode rays." "Quantitative differences in the behaviour of different bodies, have however revealed themselves" "Judging by my experiments up to now, platinum is the best for generating the most powerful cathode rays." He evidently alludes to the "focus tube" & states concerning it "the x-rays in this apparatus start from the anode" "As regards the intensity of the x-rays it is a matter of indifference whether or no the spot at which these rays are generated be the anode." With a special view to experimenting with alternate currents from a Tesla transformer Röntgen is having constructed a discharge apparatus "in which both electrodes are concave aluminium mirrors, their axes being at right angles; at the common center of curvature there is a "cathode-ray catching" sheet of "platinum", in fact a double" focus tube".

The date of Röntgen's second communication is March 9. 1896.

"Radiographic Projection by Röntgen's Method"

Examples etc.

being part II of a Dissertation for the degree of M.D. in the University of Edinburgh by

William Cotton.
M.A.: M.B., C.M. Ed.
D.P.H. Cantab.

~~April~~ May 5. 1896.

List of Illustrations.

(N.B. The majority of above are printed in "Solio" glatino-chloride paper which shows much detail & takes a high finish, but is not permanent in the same way as "a" platinotype paper is. Some duplicates in latter are: sent).

. 11.22 "Eheu! fugaces ... labuntur anni". Q.H.F.

W.C.

Published Papers.

By Dr. WILLIAM COTTON, M.A., M.D., D.P.H., on X-rays.
Late Capt. R.A.M.C. (T.F.) B.E.F. France

1. 1896. "Radiographic Projection by Röntgen's Method." *(Thesis for Graduation as M.D., Edinburgh.)*
2. 1901. "X-ray Photographs as Pictures." *(Bristol Medico-Chirurgical Journal—June.)*
3. 1902. "Stereoscopic X-ray Representation." *(Bristol Medico-Chirurgical Journal—September.)*
4. ,, "The True and False Perspective of X-ray Representation." *(Archives of the Röntgen Ray—July.)*
5. 1903. "Some Peculiarities of the X-ray Image." *(Edinburgh Medical Journal—July.)*
6. 1904. "Perspective Nature of X-ray Projection." *(Journal of the Röntgen Society—December.)*
7. 1905. "Twin X-ray Representation and the Reflecting Stereoscope." *(Bristol Medico-Chirurgical Journal—September.)*
8. ,, "The True Principles of X-ray Interpretation." *(Archives of the Röntgen Ray. No. 63. Vol. X.)*
9. 1906. "Some Principles and Fallacies of X-ray Interpretation." *(The Practitioner. "X-rays in Diagnosis.")*
10. 1907. "Proportional Representation and the Comparison of Radiographs." *(Bristol Medico-Chirurgical Journal—December.)*
11. 1909. "The Principle of Proportional Representation in Clinical Radiography." *(The Practitioner—March.)*
12. ,, "Radiographic Localisation by means of Visible Shadows." *(Journal of the Röntgen Society—July.)*
13. 1910. "The Essential Ambiguity of X-ray Representation and some Methods of Solution." *(Journal of the Röntgen Society—April.)*
14. ,, "Radiographic Estimation of Simple Enlargement by means of Visible Shadows." *(Bristol Medico-Chirurgical Journal—September.)*
15. ,, "Some Practical Points in the Interpretation of X-ray Pictures and Outlines." *(Letters to the Editor of the British Medical Journal—June, July and September.)*
16. ,, "Proportional Representation." *(Archives of the Röntgen Ray—October.)*
17. 1911. "The Fluoroscopic Diagnosis of Direction by a Plane Mirror upon the Screen." *(The Practitioner—May.)*
18. ,, "Design for an Elementary Radiographic Camera." *(The Bristol Medico-Chirurgical Journal—June.)*
19. 1912. "The Right and the Wrong Side of the X-ray Picture; has a mistake been made?" (Lantern Slide Demonstration.) *(Journal of the Röntgen Society—April.)*
20. ,, A complete Paper with the same title as the last. *(Bristol Medico-Chirurgical Journal—September.)*
21. 1913. "'The Episcope' an Optical Instrument for X-ray use." *(Archives of the Röntgen Ray—February.)*
22. ,, "Direct Combined Examination of Single Radiograph and Patient: the Episcope." *(The Practitioner—June.)*
23. ,, "The Episcope, a new Instrument for the Utilisation of the Single X-ray Print." *(Journal of the Röntgen Society—July.)*
24. 1914. "The Radiographic Centroscope, and the Radiographic Episcope." *(Bristol Medico-Chirurgical Journal—September.)*
25. 1915. "The X-ray Episcope, and the X-ray Camera." *(In the Press.)*
26. ,, "Some Principles of X-ray Localisation." *(The Practitioner—April.)*
27. ,, "An Apparatus for X-ray Localisation." *(~~Bristol~~ Irish Medical Journal—March.)*
28. 1916. "Ten Months in France with a Field-Service X-ray Outfit." *(Bristol Medico-Chirurgical Journal—December.)*
29. 1920. "Three Years Radiography at the Base in France." (~~*In the Press.*~~ The Practitioner — Oct.)
30. ,, "Trigraphic or Anatomical Localisation." (~~*In the Press*~~ The British Medical Journal. March)
31. 1921 "X-ray Localisation at the Base in France" (The Practitioner. March).
32. 1921. "Hints to Camp Medical Radiographers" (In the Press).

P.T.O.

Also in Collaboration:—

1897 "The Effect of the Röntgen Rays on Calculi"
by James Swain F.R.C.S. Assistant Surgeon Bristol Royal Infirmary
(Bristol Medico-Chirurgical Journal – [illegible])

1899. "A simple form of Influence machine for X-ray Work"
by Thomas Clark, plumber
(Bristol Medico-Chirurgical Journal – Sept)

PUBLISHED AND OTHER PAPERS ON X-RAYS

By Dr. WILLIAM COTTON

1. 1896—" Radiographic Projection by Röntgen's Method."
   (Thesis for Graduation as M.D., Edinburgh.)
2. 1901—" X-ray Photographs as Pictures."
   (*Bristol Medico-Chirurgical Journal*—June.)
3. 1902—" Stereoscopic X-ray Representation."
   (*Bristol Medico-Chirurgical Journal*—September.)
4. 1902—" The True and False Perspective of X-ray Representation."
   (*Archives of the Röntgen Ray*—July.)
5. 1903—" Some Peculiarities of the X-ray Image."
   (*Edinburgh Medical Journal*—July.)
6. 1904—" Perspective Nature of X-ray Projection."
   (*Journal of the Röntgen Society*—December.)
7. 1905—" Twin X-ray Representation and the Reflecting Stereoscope."
   (*Bristol Medico-Chirurgical Journal*—September.)
8. 1905—" The True Principles of X-ray Interpretation."
   (*Archives of the Röntgen Ray*, No. 63, Vol. X.)
9. 1906—" Some Principles and Fallacies of X-ray Interpretation."
   (*The Practitioner*—" X-rays in Diagnosis.")
10. 1907—" Proportional Representation and the Comparison of Radiographs."
    (*Bristol Medico-Chirurgical Journal*—December.)
11. 1909—" The Principle of Proportional Representation in Clinical Radiography."
    (*The Practitioner*—March.)
12. 1909—" Radiographic Localisation by means of Visible Shadows."
    (*Journal of the Röntgen Society*—July.)
13. 1910—" The Essential Ambiguity of X-ray Representation and some Methods of Solution."
    (*Journal of the Röntgen Society*—April.)
14. 1910—" Radiographic Estimation of Simple Enlargement by means of Visible Shadows."
    (*Bristol Medico-Chirurgical Journal*—September.)
15. 1910—" Some Practical Points in the Interpretation of X-ray Pictures and Outlines."
    (Letters to the Editor of the *British Medical Journal*—June, July and September.)
16. 1910—" Proportional Representation."
    (*Archives of the Röntgen Ray*—October.)
17. 1911—" The Fluoroscopic Diagnosis of Direction by a Plane Mirror upon the Screen."
    (*The Practitioner*—May.)
18. 1911—" Design for an Elementary Radiographic Camera."
    (*The Bristol Medico-Chirurgical Journal*—June.)
19. 1912—" The Right and the Wrong Side of the X-ray Picture: has a mistake been made?"
    (Lantern Slide Demonstration.)
    (*Journal of the Röntgen Society*—April.)

20. 1912—A complete Paper with the same title as the last.
(*Bristol Medico-Chirurgical Journal*—September.)

21. 1913—" The Episcope—an Optical Instrument for X-ray use."
(*Archives of the Röntgen Ray*—February.)

22. 1913—" Direct Combined Examination of Single Radiograph and Patient : the Episcope."
(*The Practitioner*—June.)

23. 1913—" The Episcope—a new Instrument for the Utilisation of the Single X-ray Print."
(*Journal of the Röntgen Society*—July.)

24. 1914—" The Radiographic Centroscope, and the Radiographic Episcope."
(*Bristol Medico-Chirurgical Journal*—September.)

25. 1915—" The X-ray Episcope, and the X-ray Camera."
(In the Press.)

26. 1915—" Some Principles of X-ray Localisation."
(*The Practitioner*—April.)

27. 1915—" An Apparatus for X-ray Localisation."
(*British Medical Journal*—March.)

28. 1916—" Ten Months in France with a Field-Service X-ray Outfit."
(*Bristol Medico-Chirurgical Journal*—December.)

29. 1920—" Three Years Radiography at the Base in France."
(*The Practitioner*—October.)

30. 1920—" Trigraphic or Anatomical Localisation."
(*The British Medical Journal*—March.)

31. 1921—" X-ray Localisation at the Base in France."
(*The Practitioner*—March.)

32. 1922—" Hints for X-ray Medical Officers Overseas."
(In the Press.)

33. 1923—" The Perspective Delineation of the Heart by X-rays—the Episcope and the Skiaphore."
(In the Press.)

34. 1924—" Some Elementary Pitfalls of X-ray Interpretation."
(*The Practitioner*—July.)

35. 1925—" Perspective in Relation to X-ray Interpretation."
(Privately Printed.)

36. 1925—" The Readings of Skiagrams."
(Letter to the Editor, *B.M. J.*—March.)

IN COLLABORATION :

1897—" The Effect of the Röntgen Rays on Calculi," by James Swain, F.R.C.S., Asst. Surgeon, Bristol Royal Infirmary. (*Bristol Medico-Chirurgical Journal*—March.)

1899—" A Simple Form of Influence Machine for X-ray Work " (namely Mr. Thomas Clark's Sectorless Wimshurst Machine). (*Bristol Medico-Chirurgical Journal*—September.)