AIDS TO DEFINITION IN X-RAY WORK.

BY CAPTAIN B. T. LANG.
Royal Army Medical Corps.
Sometime Officer-in-Command No 2 (Ladies' College, Cheltenham) Mobile X-ray Unit.

AN accurate knowledge of the exact situation of a foreign body in relationship to the eye is often a matter of considerable importance to the ophthalmic surgeon. All the types of machine more commonly in use for the localization of foreign bodies in the eye or orbit have some disadvantage. Therefore, some months ago, I set about designing a new form that should incorporate great simplicity with extreme accuracy. It was essential that the definition of the negative should be the best possible, and I therefore investigated the question of the most suitable form of diaphragm to employ.

In all X-ray work, but particularly in ophthalmic X-ray work, one strives to produce negatives showing sharply defined shadows with clear-cut edges. This could easily be obtained, if only all the X-rays that eventually fell on the plate arose from a single point on the anti-cathode of the X-ray tube.

Unfortunately, this is not the case. Formerly, one had difficulty in producing a high-tension current travelling in one direction only. This resulted in primary X-rays being produced in at least two places in the X-ray tube, with a resulting duplication of the shadow and blurring of the edge. But with improved apparatus, valve tubes and X-ray tubes, this difficulty has been overcome and primary rays arise, in every well constituted outfit, from a single point on the anti-cathode. But wherever these primary rays strike objects, for instance the glass walls of the X-ray tube, they set up secondary rays which are also capable of influencing the X-ray plate, and some of these secondary rays can pass, as can be seen in Diagram 1, obliquely behind the foreign body and thus blur the edges of the shadow.

The foreign body "O" lying in the stream of the primary X-rays arising from the anti-cathode "AC" of the tube "T" throws the shadow "S_1." This would be uniformly densely black were it not for the secondary rays "SR" arising from the walls of the tube which pass obliquely behind the object "O" and illuminate the margins of the shadow. And it is for this reason that it is only the central portion "S" that remains densely black. Further, the foreign body "O" shades a portion of the surrounding area from some of these secondary rays, and, therefore, the edge of the shadow, instead of being clearly cut, shades gradually from the deep black of "S" through the slightly illuminated margin "S_1"; and through the slightly shaded zone "S_2" to the fully illuminated surrounding area.

In the diagram, the foreign body is very large and throws a shadow that is so large that a considerable portion of it is entirely free from illumination by secondary rays. A foreign body about half the diameter of the above would throw a shadow only a very small area of which will be free from secondary rays. A smaller foreign body still will have the whole of its primary shadow more or less illuminated; while the minute foreign body, with which one almost always has to deal in ophthalmic work, throws so faint a shadow that its presence may be entirely overlooked.

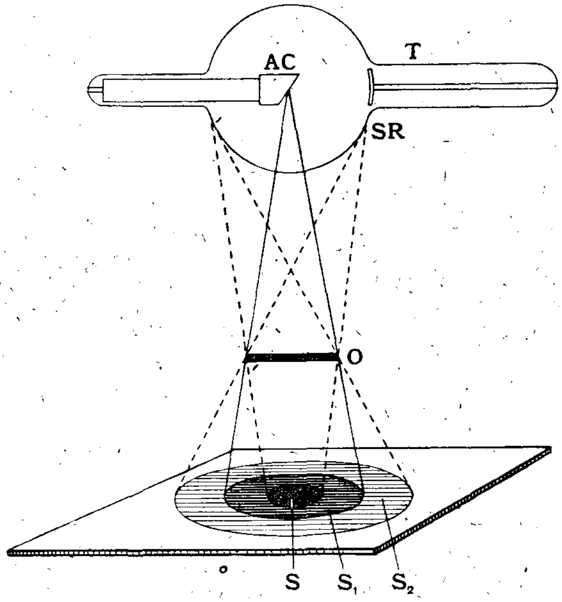


DIAGRAM 1.

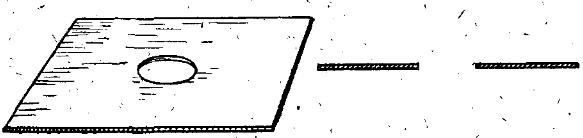


DIAGRAM 2. DIAGRAM 2A.

In order to improve the definition of the shadow, diaphragms are used. Two types are recognized :—

(1) The ordinary flat disk or plate type, consisting of a piece of material opaque to X-rays in which a central hole has been cut. See Diagram 2.

(2) The tube, cylinder, or cone diaphragm in which in addition to the above, a cylindrical or conical portion of similar material is attached to the edges of the central hole. See Diagram 3.

Diagram 4 shows, that by employing a plane diaphragm "D" the size of the densely black shadow "S" is greatly increased, and that this is brought about by screening off a large area of the tube wall from which these disturbing secondary rays arise.

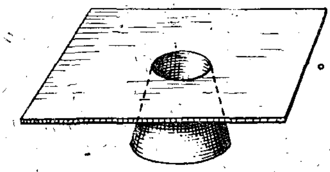


DIAGRAM 3.

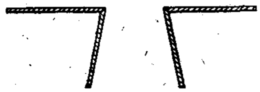


DIAGRAM 3A

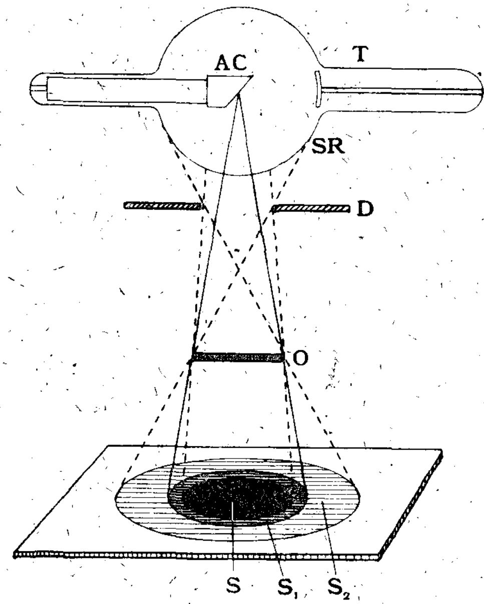


DIAGRAM 4.

It is obvious that the more closely the size of the diaphragm approaches the size of the foreign body, the smaller will be the difference between the densely black area "S" and the partially illuminated area "S_1." For this reason, the smaller the diaphragm the better the definition.

Diagram 5 shows that the employment of a tube, cylinder or cone diaphragm "CD" of the same sized aperture, in no way improves the definition of the theoretical shadow "S_1."

Now it is a matter of common knowledge—a point about which every X-ray worker is agreed—that the definition obtained with a tube diaphragm is superior to that obtained with a flat one, more particularly when dealing with thick tissue such as the head in ophthalmic work, or the hip joint.

Many explanations have, from time to time, been brought forward to account for this superiority of the tube diaphragm, but none as far as I am aware completely satisfies the facts.

As stated above, it is well known that secondary rays arise from any object on which primary rays impinge. Therefore, of course, if the foreign body were lying within a limb, for example, instead of being suspended in the air, many secondary rays would arise from the tissues of the limb, a large number of which would fall on the plate and blur the edges of the shadows. Since, however, the aperture of the plane and the cone diaphragm is the same, it is presumed that the same number of secondary rays would arise in each case. Therefore, one must look elsewhere for the explanation of the superiority of the cone diaphragm.

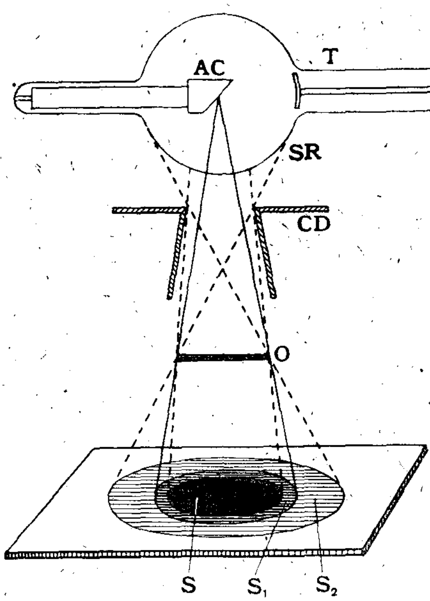
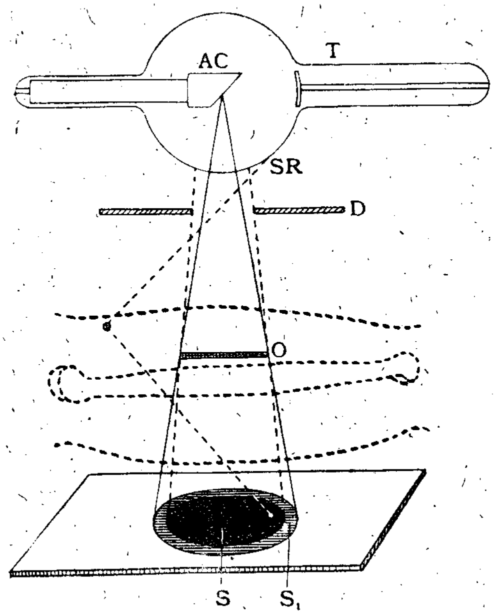


DIAGRAM 5.

The only apparent difference between the two types is the ability of the cone portion of the cone diaphragm to protect the surrounding parts of the limb from the secondary rays arising from the tube walls. Now these secondary rays, when they fall on tissues, set up new rays again, and these conceivably might influence the definition of the shadows. This is clearly shown in Diagrams 6 and 7.

Diagram 6 shows one of these rays "SR" falling on the limb and there setting up new rays which fall on the densely black shadow "S" and reduce its blackness.

Diagram 7 shows how the cone part of the cone diaphragm protects the limb and, therefore, eliminates the possibility of this disturbing ray arising.



DIAGRAM

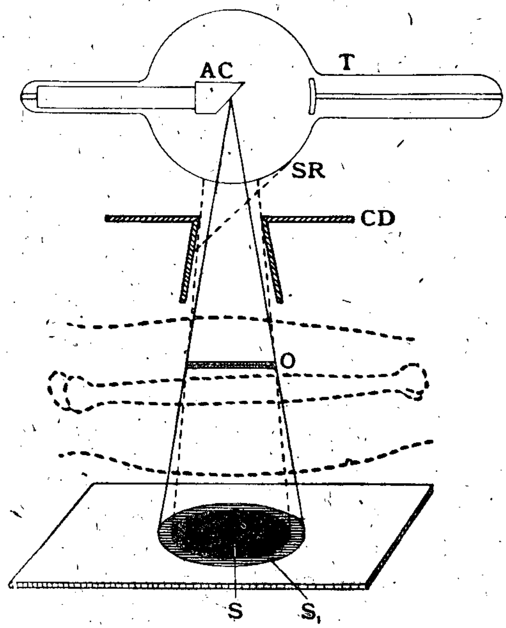


DIAGRAM 7.

These new rays would obviously have only very slight penetrating power, and their capacity for blurring the shadow seemed doubtful, but I saw no other logical explanation of how the cone diaphragm could act in a manner superior to that of the plane diaphragm "D."

But in order conclusively to prove the point, I designed the following experiment.

I employed a large plane diaphragm "D" made of lead three millimetres thick—see Diagram 8—and a lead disk "D_1" also three millimetres thick. This was of such size, and so placed, that no primary X-rays fell on the area "A." In this part, at "P," I placed an X-ray plate "P_1" half of which was covered with a piece of lead three millimetres thick.

I then exposed it for three minutes, with about four milliamperes of current passing through a tube of about Benoist 7, the tube being fifty cubic centimetres from the plate.

I next interposed a patient between the disk "D_1" and the area "A" —see Diagram 9—and exposed another plate "P_2" under otherwise similar conditions.

Now, if the theory suggested above be true, the secondary rays arising from the tube walls will fall copiously on the patient's body, and very many new rays will arise, many of which will fall on the plate "P_2" and will fog the uncovered half, which on development should be quite dark. While the plate "P_1" since there is nothing in this case from which secondary rays can arise, should be entirely free from fog.

When I developed the plates, I found, to my surprise, that nothing of the sort had happened.

The plate "P_1" on development showed slight, very slight fogging of the half uncovered by the lead, while the other half was entirely clear. This showed me that the three millimetres of lead of "D_1" was not enough to cut off all the primary rays, but six millimetres (made up by supplementing the three millimetres of "D_1" with the three millimetres of lead laid on the plate) was ample.

The plate "P_2" was completely free from fog. This showed that the patient's body had made up for the deficiencies of the disk "D_1"; and that no secondary rays had affected the plate. So my theory fell to pieces.

The question then arose, what was the peculiar property of the tube diaphragm whereby one was enabled to obtain with it results superior to those obtained with a plane one?

I next started testing the opaqueness of the ordinary X-ray diaphragm for primary X-rays. And I found, to my great astonishment, that all the plane diaphragms that I tested were incapable of protecting a plate from being fogged by about 240 milliampere seconds exposure with a Benoist 7 tube. These diaphragms were quite capable of screening off all the secondary rays arising from the glass walls of the tube, and some of the softer rays arising from the anti-cathode, but they were penetrated by the harder rays.

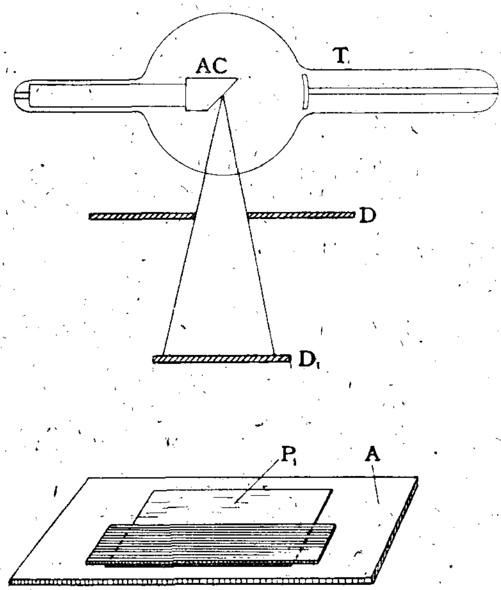


DIAGRAM 8.

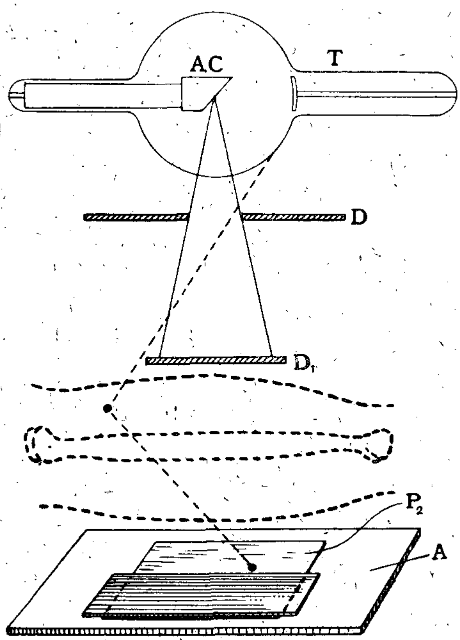


DIAGRAM 9.

I found that it was only when the rays had to pass the entire length of the cylindrical or conical portion of the cylinder or cone diaphragm, that the material was of sufficient thickness to protect the plate, and that it was in this area only that the plate was protected.

If a tube diaphragm of lead glass be placed on a plate so that the normal ray from the X-ray tube passes down its central axis and an exposure be made, it will be found on development that the base of the diaphragm only partially protects the plate, but that there is a clear entirely fog-free ring corresponding to the tube. With this new fact at my disposal, I started using plane lead diaphragms at least five millimetres thick, and with them obtained results just as good as those obtained with a tube diaphragm.

So that it would appear that the true explanation of the superior action of the cone diaphragm is, that owing to the fact that it is quite opaque it entirely protects the surrounding tissues from X-rays.

The ordinary diaphragm allows the hard primary X-rays to pass through it. These enter the surrounding tissue, and there set up secondary rays which blur the shadow.

Diaphragms are usually mounted close to the tube wall. This is done because for any one given sized pencil of X-rays, the nearer the diaphragm is to the tube the smaller may the hole in the diaphragm be, and the smaller the hole the less the area of the tube wall uncovered, and therefore, the less the quantity of secondary rays arising from the wall that can fall on the patient. But, as shown above, the secondary rays arising in this manner are only of the very slighest importance, if of any importance at all. Therefore, this assiduous guarding of the tube wall is quite superfluous.

So long as the tissues are entirely and completely shielded from unnecessary primary X-rays, it is of no practical importance where the diaphragm is placed. It may be convenient, on occasion, to place it in contact with the patient.

I believe the reason for the adoption of semi-opaque diaphragms to be a twofold one.

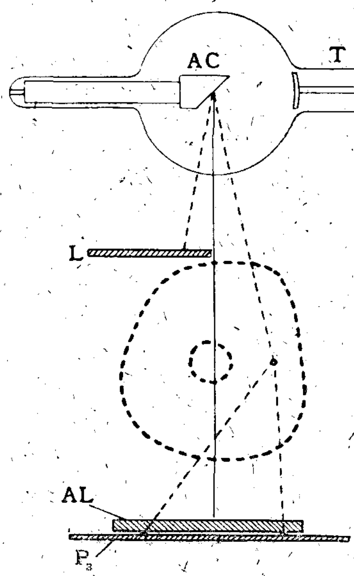
In the first place, if one employs a sheet metal diaphragm near the tube, there is always the risk that it may acquire a statical charge; this may discharge into the tube through the glass wall, thereby perforating and destroying the tube. This may be obviated either by "earthing" the diaphragm, or by mounting it farther away from the tube, which, as seen above, is of no disadvantage.

In the second place, non-metallic material opaque to X-rays is both bulky and heavy, and instrument makers have for years been trying to keep their tube stands and holders as light as possible.

If the above explanation be true, then there must be a great deal of general fog produced by these secondary rays when a thick structure such as a head or hip is being X-rayed.

In order to determine the quantity of this fog, I carried out the experiment shown in Diagram 10.

I placed a sheet of lead "L" about eight millimetres thick between the tube and the patient, so arranged that it shaded half the X-ray plate from the primary rays. I then gave an ordinary exposure. On developing the plate, I was able to see on one half the ordinary X-ray negative, and on the other, where no primary rays had fallen, a general fog which was densest where it abutted on to the radiograph and gradually faded off in those parts of the plate that were farthest under the lead screen.



DIAGRA 10.

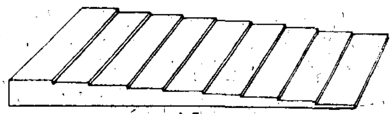


DIAGRAM 11.

These secondary rays are of necessity soft, i.e., of low penetration, and I therefore conceived the idea of filtering them off by means of thin aluminium sheet. In order to determine what thickness would be most suitable, I assembled several sheets, each about half a millimetre thick, in the form of a staircase, as can be seen in Diagram 11. I now placed this between the patient and the plate as may be seen in Diagram 10, where it is labelled "AL." I was thus enabled to determine the effect of screening off various quantities of these secondary rays, both on that part of the plate where the primary rays fell and on the part where there were only secondary rays. I observed, that within limits, small thicknesses of aluminium cut off some of these secondary rays with resulting improvement in the contrast of the negative. In that part where the aluminium was four millimetres thick, nearly all the secondary rays were cut off. This thickness naturally also cut off some of the primary rays as well, but the total result gave the effect of enhanced contrast, but detail was wanting, as the negative in this area was underexposed.

Many factors enter into the problem, such as:—

Nature and thickness of the part to be X-rayed.

Penetration of the tube and exposure.

Make of plate and type of developer.

Temperature of developer and time of development.

I, unfortunately, have had neither time nor opportunity to bring this part of work to a definite conclusion. I imagine that it will be essential to carry out the experiments with a Coolidge tube, as with no other can one regulate and maintain the penetration with any approach to scientific accuracy.

In conclusion, a cone diaphragm gives clearer, sharper X-ray negatives, because it is more opaque than the other forms, and for no other reason.

A cone diaphragm has three other advantages:—

It protects the operator from the secondary rays arising from the tube wall, should the table not be fitted with the usual opaque aprons.

If the tube be properly centred, the cone diaphragm clearly indicates the size and direction of the pencil of X-rays, and is then very useful, when working from above, in aiding one to determine what area will be exposed to X-rays.

The cone diaphragm can be, and often is, used as a compressor diaphragm, to press the intestines on one side when X-raying the kidney area for example.

(2) I believe that when associated with appropriate exposure and development, the filtering off of some of the secondary rays, as mentioned above, will be found advantageous in increasing the contrast and detail.