X-RAY FLUOROSCOPY WITH ENLARGED IMAGE

by G. C. E. BURGER, B. COMBEE and J. H. van der TUUK.

The intrinsic blurring of a fluoroscope screen (for instance about 1 mm) interferes with the observation of small details showing little contrast. By placing the object at a distance from the screen and close to the focus an enlarged image is obtained in which the (constant) screen blurring has relatively less effect. In order to prevent the geometrical blurring, which increases rapidly upon enlargement, from spoiling the desired effect, X-ray tubes with a very small focus must be used for enlarged fluoroscopy. Upon enlargement all the contrasts in the image also increase considerably, due to the fact that with a large distance between object and screen practically no secondary, scattered radiation falls on the screen. By the improvement in definition and contrast certain groups of otherwise invisible details become perceptible, while at the same time the enlarged images can be studied more quickly and with less fatigue. In certain cases the enlargement is accompanied by a significant loss in (primary) screen brightness. The detrimental effect of this on the perceptibility of details is analysed. In medical diagnostics the enlargement makes it necessary to limit the time a patient is kept under observation. Phantom tests and a small series of examinations of lung patients have led to the conclusion that enlargement may well constitute an appreciable advance in diagnostics. The technique to be followed in this case has to be further worked out. In a separate section a description is given of the Philips X-ray tubes which were specially developed for the experiments in question. They work with electrostatic focusing and provide a choice of two foci, one normal focus of 2.0 or 1.2 mm width and a fine focus of 0.3 mm width.

Blurring of the image in fluoroscopy

The shadow picture obtained in X-ray screening of any object is always affected by a certain blurring, which may be ascribed two to causes. In the first place the focus of the X-ray from which the projecting rays are emitted is not a point. The finite width of the focus causes a "geometrical blurring" $O_g$ (half shadow width), which according to fig. 1 is given by

$$O_g = \frac{b}{a f}$$

(1)

where $a$ and $b$ are respectively the distance between object and focus and that between object and screen. In the second place the mechanism of the excitation of the light on the fluorescent screen causes a blurring of the image. Every fluoroscope screen has for this reason an intrinsic blurring, the "screen blurring", $O_s$, which for a normally good screen may amount, for example, to 0.6 to 1.0 mm. The geometrical blurring is usually smaller. For instance in the case of normal lung screening $a \approx 50$ cm, $b \approx 20$ cm, and foci of for instance 1.2 mm width are used; for such a case $O_g \approx 0.5$ mm.

In the testing of materials as well as in medical diagnostics the object in fluoroscopy is to be able to observe very small objects, often with little contrast (minute holes or cracks, errors in assembly of the piece of work; disease nuclei in the lungs, small ulcers in the stomach, etc.) The blurring of the image will be a handicap in such cases. We shall explain this further, but for the present it may be stated roughly that the perceptibility of

---

Fig. 1. Due to the finite width of the focus ($F$) the X-ray shadow picture of the object ($O$) on the fluoroscope screen ($S$) has a geometrical blurring of $O_g$.
a detail with little contrast will become doubtful as soon as the detail is no larger than the blurring of the image. With the above mentioned numerical values of the blurring, therefore, all kinds of details (sometimes important ones) smaller than about 1 mm would escape observation.

Principle of enlarged fluoroscopy

It is obvious that only in case of necessity will such a limitation be tolerated. There now exists a method, which in principle is very simple, to improve the perceptibility of small details, namely fluoroscopy with enlarged image. For that purpose the arrangement of fig. 1 is modified in such a way that \( b \) becomes several times as large as \( a \); see fig. 2. It may be read off from the figure that the object is projected on the screen enlarged by a factor

\[
v = \frac{b + a}{a}.
\]

Since all details are enlarged in the same proportion (or, with a thick object, in approximately the same proportion), while the intrinsic screen blurring remains unaltered, small details then have a greater chance to show up above the screen blurring: this would indeed mean that with the change in distance \( b/a \) mentioned the geometrical blurring would increase considerably (equation (1)) and therefore neutralize the advantage gained. It is possible, however, to compensate the increase of the factor \( b/a \) in equation (1) by making the width of the focus \( f \) correspondingly smaller. For the practical application of enlarged fluoroscopy therefore, special X-ray tubes with a very small focus are desired.

In the following we shall replace this rough picture with a more quantitative formulation and also discuss the influence of various other factors involved in enlarged screening. It will be found that the situation for the testing of materials is somewhat different from that for medical diagnostics. The possibilities of medical applications, which have been studied carefully by us in recent years, will be dealt with in somewhat more detail. At the same time the X-ray tubes especially developed by Philips in connection with the magnification technique will be described.

The improvement attainable by magnification

The critical size of detail

It is unnecessary to prove that a larger and sharper image is more pleasant and offers more certainty of judgement. But it may be asked whether in the enlarged, relatively sharper image details can indeed be observed which were formerly invisible. In order to answer this question it is first necessary to consider the detrimental effect of the blurring.

To begin with, we consider the case where \( b \) is very small; no enlargement is thus employed \((v \approx 1)\) and we also assume a point focus, so that the geometrical blurring is zero. Outside the shadow of the detail to be observed let the screen brightness be \( H_0 \) in the middle of the shadow \( H_1 \) (see fig. 3a). At the edge of the shadow, due to the screen blurring, the brightness does not fall abruptly from the value \( H_3 \) to the value \( H_1 \), but there is a transition region of width \( O_3 \) in which the brightness gradually varies from \( H_3 \) to \( H_1 \) (for the sake of simplicity we consider this variation to be linear). For the perceptibility of the detail drawn in fig. 3a, where the diameter \( d \) is larger than the screen blurring \( O_3 \), this gradual transition of brightness has no unfavourable result. If the contrast between \( H_1 \) and \( H_2 \) is equal to or larger than the minimum contrast which the observer can still just distinguish at the angle of vision corresponding to \( d \), the detail will be observed in spite of the blurring 1).

The situation becomes different when the detail is smaller than the screen blurring. In fig. 3b it may be seen that the regions of the transition in brightness at opposite edges now partially overlap. The brightness behind the detail nowhere falls to the low value \( H_2 \), i.e. the screen blurring results in a decrease in contrast. Thus if a detail of the size \( d < O_3 \) without the screen blurring has just sufficient contrast to be observed, then

1) With decreasing angle of vision the value of the minimum perceptible contrast increases. Due to the cutting down of the region of full contrast of a detail following from fig. 3a (difference in brightness \( H_3-H_1 \) therefore, perceptibility is somewhat unfavourably affected. The impression of contrast upon a gradual transition in brightness \( H_1 \) is also probably smaller than upon an abrupt transition.
owing to the decrease in contrast caused by the blurring it will remain below the required size. In this case we may call \( O_s \) the critical size of detail.

\[
\text{Fig. 3. Influence of the intrinsic screen blurring } O_s \text{ on the projection of a detail of size } d. \text{ The focus is assumed to be on a point, so that the geometrical blurring } O_g = 0. \text{ The distance } b \text{ is assumed to be still so small that no appreciable enlargement occurs } (\nu \approx 1). \text{ Below, the brightness } H \text{ on the fluoroscope screen is plotted as a function of the position along a cross-section.}
\]

\( a \) Large detail, \( d > O_s \).
\( b \) Small detail, \( d < O_s \). The blurring here causes a decrease in contrast; \( d = O_s \) in this case is the "critical detail size".

Let us now consider the same case when screening with magnification \((\nu > 1)\). The shadow picture of the detail becomes \( \nu \) times as large, and the constant screen blurring \( O_s \) can now only cause a decrease in contrast when \( \nu \cdot d < O_s \), i.e., in the case of details which are \( \nu \) times as small as before. Thus only \( \nu \) times smaller details are apt to escape observation. This is the effect with which we are concerned in the enlargement.

The effect is partially neutralized due to the fact that upon enlargement the total blurring is in any case increased; as already mentioned the geometrical blurring now comes to the fore. If we assume for the moment that only the geometrical blurring \( O_g \) is present \((O_s = 0)\), then the situation for a large and a small detail is represented by fig. 4a and 4b respectively. \( O_g \) decreases the contrast for small details in exactly the same way as explained above for the screen blurring \( O_s \). "Decrease of contrast"

is now only another expression for the simple fact that the fluoroscope screen is no longer affected by the core shadow of the detail (see fig. 4b). The condition for decrease of the contrast is, analogous to the above, \( \nu \cdot d < O_g \) and since

\[
O_g = (\nu - 1) \cdot f
\]

(see equations (1) and (2)), the perceptibility is unfavourably affected for details with

\[
d < f (1 - \frac{1}{\nu}).
\]

If, therefore, the enlargement were very large \((\nu \gg 1)\), so that the screen blurring becomes negligible compared with the geometrical blurring, then according to equation (4) the critical size of detail simply becomes equal to the width of focus. From this the importance of making the focus as small as possible for magnification technique becomes quite evident.

The simultaneous occurrence of geometrical and screen blurring results in a total blurring \( O_t \), which can be approximately represented 2) by

\[
O_t = \sqrt{O_g^2 + O_s^2}
\]

Decrease in contrast occurs at \( \nu \cdot d < O_t \), and thus

\[
O_t = \sqrt{O_g^2 + O_s^2}
\]

the critical size of detail in the general case is

$$d = \frac{1}{v} \left\{ (v-1)^2 f^2 + O_s^2 \right\}$$

or, if the formula is written in the non-dimensional form

$$\frac{d}{O_s} = \frac{1}{v} \sqrt{(v-1)^2 \left( \frac{f}{O_s} \right)^2 + 1}$$

In fig. 5 this relation is represented graphically. The ratio \(d/O_s\) is plotted as a function of the enlargement \(v\) for different values of the parameter.

![Graph](image)

Fig. 5. In the presence of a screen blurring \(O_s\) and simultaneously a geometrical blurring (focus width \(f\)) the critical size of particle \(d\), below which a decrease in contrast occurs due to the blurring, is given by equation (7). The ratio \(d/O_s\) is here plotted according to this equation as a function of the enlargement factor \(v\), with the quotient \(f/O_s\) as parameter. Each curve passes through a minimum at an enlargement factor \(v_m = 1 + (O_s/f)^2\); the level of these minima is given by \((d/O_s)_{\text{min}} = 1/v_m\) (dotted-line curve). With very small foci, for instance for \(f/O_s = 0.3\), however, at an enlargement of \(v \approx 4\) practically the whole theoretical gain is already obtained.

\(f/O_s\). It may be seen that with a small enough focus the critical size of detail steadily decreases with increasing enlargement, but that at the same time this decrease is limited by the width of focus \(f\). At the value \(f = 0.3\) mm, which has been realized in the X-ray tubes to be described later, and with \(O_s = 1.0\) mm, the practical enlargement will be not more than 4 times, since the further decrease of \(d\) is then no longer appreciable. The critical size of detail here is \(d = 1/3\) mm, while without enlargement \(d = O_s = 1\) mm.

The scattered radiation

In addition to diminishing the influence of the screen blurring enlargement also has another, favourable effect which lies quite outside the considerations already discussed. The longer the distance \(b\) between object and fluoroscope screen, the smaller the percentage of secondary X-radiation \(^3\) scattered by the object which falls on the screen. This scattered radiation gives a uniform fog over the image which reduces all contrasts — an effect, therefore, which in the case of enlargement becomes less potent or even almost disappears. A gain in contrast is thus obtained over the whole image. The degree to which the contrasts may increase is illustrated by the fact for instance in lung fluoroscopy the scattered radiation may have the same intensity as the primary radiation and in screening of the abdomen its intensity may even be three or four times as great \(^3\).

The effect of the enhanced contrasts is further increased by the fact that upon enlargement the visual angles within which all the details of the object are seen increase proportionally. For details with a larger visual angle an observer has a higher sensitivity to contrast (cf. footnote \(^1\)).

In fig. 6 two photographs (\(b\) and \(c\)) are given of an object \((a)\) on the fluoroscope screen with and without enlargement. It may be seen that small details originally invisible or almost so are rendered visible and the contrasts in the enlarged image become larger. For the sake of comparison a reproduction \((d)\) is also given of the normal fluoroscopic image subsequently enlarged optically. Since the screen blurring is here also enlarged and the fog due to the scattered radiation remains, no improvement is obtained.

Ease of observation

A comparison of figures 6\(b\) and 6\(c\) also gives an idea of the more convenient and easier observation of the enlarged image to which reference has already been made. The concrete advantage of this in practice is that perception of details is much quicker and less fatiguing.

The screen brightness

Influence on the improvement obtained

It would be premature to conclude from the above that in every case (with sufficiently small focus) enlargement would be an advantage. We have until now disregarded the fact that upon enlargement the brightness of the image on the fluoroscope screen may decrease.

We must, here make a distinction between the contribution to the brightness of the primary (the image-forming) and that of the secondary (scattered) X-radiation. The contribution to the brightness of the secondary radiation decreases in any case upon enlargement. This means that all kinds of physiological factors which remain to be discussed are affected unfavourably to some extent, but on

\(^3\) See for example W. J. Oosterkamp, Combating the scattered radiation in the medical X-ray image, Philips Techn. Rev. 8, 183, 1946.
the whole the disappearance of the scattered radiation can only be favourable. However, the contribution to the brightness of the primary radiation may also decrease appreciably upon enlargement. We shall see presently that in the testing of materials this is very often the case, while in medical diagnostics it need not occur invariably.

With decreasing brightness of screen the visual acuity and sensitivity to contrast of the observer diminish. The advantage of the increase in all contrasts by enlargement (including the already mentioned higher sensitivity due to the larger angles of vision) is partly neutralized by a diminution of the sensitivity to contrast. As to the blurring the critical size of detail caused thereby does not depend upon the brightness, but the decrease in contrast in the case of details with dimensions smaller than the critical, when the observer's sensitivity to contrast decreases, becomes fatal already at greater contrasts, so that a larger group of details falls into the category of those no longer perceptible. Part of the gain which enlargement brings especially for the observation of small details poor in contrast is thus lost again.

In addition to the (small and large) details with poor contrast to which all the above discussion refers, we must also pay attention to small details with high contrast. In addition to the advantage of the sharper reproduction on the whole, enlargement gives for these details no improvement in perceptibility. A loss in brightness which accompanies the enlargement may even worsen the perceptibility of such details. This may be explained as follows:

The perceptibility of the details rich in contrast is limited by visual acuity, i.e. by the minimum angle of vision \( \theta_{\text{min}} \), in which the observer can still just distinguish a detail. When the brightness decreases due to enlargement, \( \theta_{\text{min}} \) increases. At the same time, however, the angle of vision \( \alpha \) of the detail increases proportionally with the enlargement factor \( v \). The perceptibility is unreasonably affected when \( \theta_{\text{min}} \) increases more rapidly than \( v \). The relation between \( \theta_{\text{min}} \) and the brightness is known from a number of investigations. The relation between the brightness and \( v \) may, as already indicated, be very different. If we assume, for example, a variation of the screen brightness proportional to \( 1/v^2 \), it is then found that as long as the brightness remains above a certain limit the increase of \( \alpha \) remains ahead, so that upon enlargement the "effective" visual acuity improves. At what enlargement this limit of brightness is met depends, of course, on the initial brightness (for \( v = 1 \)) and this in turn is quite different according to the nature and thickness of the object. Enlargement above a certain factor \( v \), which also depends upon the object, will thus have an unfavourable effect on the observation of the very small details rich in contrast, although the visibility of the details poor in contrast is improved. This fact may be of importance in the testing of materials.

**Screen brightness and method of enlargement**

Beginning with normal fluoroscopy where object and screen are set up close to each other, it is possible to enlarge in two ways:

1) the object and the X-ray tube can be left in the same positions and the screen placed farther away (\( a \) constant, \( b \) and thus also \( a + b \) larger);

2) the screen and the focus can be left in position and the object placed closer to the focus (\( a \) smaller, \( b \) larger, \( a + b \) constant). The screen
brightness is inversely proportional to the square of the distance \((a + b)\) between focus and screen; in the first method, therefore, upon enlargement a considerable decrease in brightness is obtained, while in the second method the (primary) brightness remains constant.

In order to avoid the above-mentioned disadvantages of a decrease in brightness, the second method seems to be the better one. For the testing of materials, however, it cannot always be applied; in particular it cannot be applied in those cases where with normal fluoroscopy, in order to obtain the greatest possible screen brightness, the object and the screen are placed as close to the X-ray tube as the dimensions of the object allow. It is therefore only possible to enlarge in such a case by placing the screen farther away, and the decrease in brightness proportional to \((a + b)^2\) or, according to equation (2), proportional to \(v^6\), must be accepted into the bargain.

In medical diagnostics, on the other hand, with normal fluoroscopy the patient is always placed at a fairly great distance from the focus in order to obtain an overall picture of the part of the body concerned \(4\). Increasing the screen brightness by placing patient and screen closer to the focus would be of no use here since a greater brightness could also be realized by increasing the current through the X-ray tube. The fact that this is not done and thus that the focus is not loaded to anywhere near the permissible limit is due to the limitation of the X-ray dose which may be administered to a patient in fluoroscopy. The intensity of radiation on the patient, by which the screen brightness is also approximately determined, is chosen so low that the doctor may devote several minutes to the perception of the fluoroscope image and still remain far below the permissible dose. If it is now desired to pass over to enlarged fluoroscopy the second method can in this case be applied, i.e. the patient can be placed closer to the focus provided a correspondingly shorter time of observation is allowed in order to keep the dose on the patient within safe limits in spite of the stronger intensity of radiation. Since the distance between focus and screen here remains unchanged the (primary) screen brightness with enlarged fluoroscopy is no less than with normal screening.

**Screen brightness and focus loading**

We have explained that for enlarged screening a much smaller focus is necessary than is normally used. If the focus is normally loaded to the limit of the power it can receive continuously per unit of surface without becoming too hot, decrease in size of the focus necessarily means a reduction in the current in the X-ray tube and thus in turn a decrease in the screen brightness. In testing materials where powers of 2 kW, for instance 150 kV\(\text{max}\), 20 mA and even more are used continuously, with the normal large foci the permissible focus temperature is indeed approached. Nevertheless, the decrease in size of the focus need not have such an unfavourable effect on the screen brightness as would follow from the ratios of the surfaces of the foci: A smaller focus has a higher specific loading capacity (at the same focus temperature). This is due to the fact that the heat developed on the small focus is dissipated not only towards the interior of the anode but to an appreciable extent also laterally (edge effect). Moreover, the specific focus loading capacity can be further increased by the employment of a rotating anode \(5\).

In medical diagnostics, due to the above-mentioned limitation of the dose on the patient, with normal fluoroscopy the permissible specific focus loading is far from being attained. A tube voltage of for instance 75 kV\(\text{max}\) with a current of 2 mA is used, i.e. a continuous loading of about 150 watts. It is here unnecessary to have the anode rotate. If the focus is now decreased in size, the focus temperature increases and at the smallest foci realized, of 0.3 mm, it is found necessary to let the anode rotate in order to be able to employ the above-mentioned 150 watts \(6\).

**Constructions of X-ray tubes with very small focus**

The requirement for obtaining a small focus is a strong concentration of the electron beam emitted by the filament of the X-ray tube. In tubes for testing materials, where the focus must sometimes


\(5\) It should be pointed out that the enlarging technique, at least as far as the improvement in definition is concerned, does not as yet offer advantages in making X-ray photographs. It is true that here too there is a kind of "screen blurring", namely that caused by the grains of the usual reinforcing screens. But in enlarged photography in the case of moving objects the blurring due to motion would increase very much, since the small focus for instantaneous photography in any case can be less heavily loaded than a large focus and for that reason alone the exposure would have to be longer. For stationary objects there is no objection to longer exposure, but just for that reason it is then possible, if greater definition is desired, to omit the reinforcing screens, so that only the very slight intrinsic lack of definition of the X-ray film itself remains.
be introduced into all kinds of cavities, the anode with the focus is often placed in a projection of the tube at a distance of 20 to 30 cm from the filament. For the small as well as for normal foci the required concentration can then only be attained by focusing with the help of one or more magnetic coils. This method gives good results but is rather elaborate. With a given magnetic field the focusing is only good for a given velocity of electrons. If it is desired to vary the voltage on the X-ray tube according to the object to be examined, the exciting current of the magnetic coils must also be accurately adjusted anew each time. If an extremely small focus is desired, this adjustment has not only to be very precise but, moreover, for the proper functioning of the tube a carefully smoothed and constant D.C. voltage is necessary, since otherwise the size of focus alternates appreciably with the ripple of the tube voltage.

In X-ray tubes where cathode and anode are placed only about 1 cm apart — in medical diagnostics such tubes are used exclusively — the problem can be solved much more satisfactorily by employing electrostatic focusing. This means that by giving a suitable shape to the cathode the potential between cathode and anode is made to vary in such a way that a strong electrostatic “lens” is formed. This focusing is independent of the tube voltage. The potential of every point in the deflecting field changes proportionally with the tube voltage; since the deflecting action on an electron is proportional to this potential, and on the other hand inversely proportional to the tube voltage which accelerates the electron, the two effects exactly cancel out each other.

The tubes with very small focus developed in the Philips laboratories (“small focus tubes”) employ electrostatic focusing. In fig. 4 the cathode of such a tube is shown. It may be seen that two spiral filaments are assembled in grooves of the cathode, one large and one very small. These can be switched on according to choice. The thin spiral furnishes the small focus of 0.3 mm width, the thick one gives a focus of 2 mm or, in other tubes, of 1.2 mm, which is intended for normal fluoroscopy and for making photographs.

The size of the focus obtained is checked in the familiar way by making a photograph of it with a pinhole camera. The aperture of this camera, which is normally made 0.2 mm, must in this case be considerably smaller (about 0.03 mm), in order to obtain a sufficiently sharp projection of the small focus.

Since the tube also serves for taking X-ray photographs when the larger focus is used, the anode is of a rotating type which in any case is desirable in order to be able to give the small focus a high load. In the usual constructions of rotating anodes the rotor runs in two ball-bearings. The guiding rings of the latter in the rotor as well as on the anode carrier have several tenths of a millimeter axial play in order to take up the difference in thermal expansion of rotor and anode carrier. For working with the small focus, however, the play referred to is undesirable. Axial vibrations of the anode might be caused; since the focus is thereby displaced perpendicular to the direction of the effective beam of X-ray, a relatively considerable increase in the apparent width of focus occurs. In order to avoid this effect a special bearing of the rotor has been made for which the axial tolerance is limited to several hundredths of a millimeter.

Practical application of enlarged fluoroscopy

In the testing of materials

The above statements about the limitation of the dosage in medical diagnostics might give the impression that the general situation for normal fluoroscopy is much more favourable for testing materials. It is possible to work with a very small distance between focus and object, with the maximum focus loading, with arbitrarily long times of observation (apart from economical considerations). These advantages, however, are practically neutralized by the disadvantage that in testing mater-
ials the objects dealt with have a much greater absorption. An iron plate 0.02 mm thick or an aluminium plate of 4.5 mm absorbs (with the same tube voltage of 75 kV) just as much as the chest of a patient. Thus in material testing the screen brightness is by no means so much more than sufficient as might be supposed. Moreover, in a workshop it is impossible to use such low screen brightness as can be used in the X-ray room of a medical establishment. The result is that the employment of fluoroscopy in material testing has always been limited to the light metals with relatively little power of absorption, such as aluminium and magnesium alloys.

Enlarged screening in the testing of materials, as was explained above, involves opposing effect in definition and brightness. Such is also the case, however, with normal screening technique. The screen blurring of 1.0 mm already mentioned is only valid for very sensitive screens having a high brightness. If a less sensitive screen were used, which gave for instance only half the brightness, the blurring would only be half as great. The compromise, which in normal fluoroscopy leads to the choice of a given screen, must be considered anew in enlarged fluoroscopy, and it is thus a priori still a question whether enlargement is really an advantage in material testing. Experience has answered this question in the affirmative and in the screening of light metals magnification technique has been employed for a number of years. We shall not go more deeply into the results obtained but refer only to the literature 7).

In medical diagnostics

We have seen that in medical diagnostics enlarged

![Fig. 9. Improvised arrangement for the enlarged screening of lung patients at the consultation bureau of the Medical Department of the Philips Factories. The patient's position is fixed, the fluoroscope screen and the X-ray tube are rigidly connected with each other and can be moved by the practitioner. Since in the periodically repeated, normal fluoroscopy the patient always stands with his back to the tube and thus the surface of the back always receives the highest radiation intensity (four times as much as a point in the middle of the lungs), for greater safety the patient is here placed with his chest facing the tube.](image)

a) Situation for normal fluoroscopy.
b) Situation for enlarged fluoroscopy.

7) See for example R. Berthold, Atlas der zerstörungsfreien Prüfverfahren T/Rö 10/7-10, J. A. Barth, Leipzig 1938.

---

**Fig. 8. Visibility tests on a phantom of “Philite” which is about equivalent to the human lung for X-ray fluoroscopy. Holes of different depth and diameter were bored in the phantom. For every depth (in mm) the diameter of the smallest perceptible hole (also in mm) is plotted.**

- a) For fluoroscopy without enlargement, focus width 0.4 mm, tube voltage 70 kV\_min, tube current 1.4 mA.
- b) For fluoroscopy with four-fold enlargement; data as in (a).
- c) On an X-ray photograph under optimum conditions.
fluoroscopy need not lead to a loss in (primary) screen brightness, but only to a limitation of the time of observation. The favourable results which could be expected from this led to a systematic investigation of the possibility of using enlarged fluoroscopy in the Medical Department of the Philips factories.

This investigation, of which several preliminary results have been published elsewhere 8), was mainly in two directions. In the first place observation tests were performed with a phantom of "Philite" which, as far as the absorption and scattering of X-ray is concerned, corresponds approximately to the chest of a patient. A number of holes of different diameter, and depth were bored in the phantom. The graphic representation in fig. 8 shows the visibility of these holes with normal fluoroscopy (a), when screening with four-fold enlargement (b) and on a good X-ray photograph (c). It may be seen that there is a significant improvement between normal and enlarged fluoroscopy. Moreover, these experiments already showed how important it was that the perception could take place more easily and more quickly with the large image than with the small one. Because of this the necessary shortening of the time of observation of a patient (to for instance 10 to 20 sec.) already mentioned is less of a disadvantage.

In the second place a group of lung patients in the routine examinations of the consultation bureau were examined not only with ordinary fluoroscopy but also with enlarged image. The improvised arrangement with which these experiments were carried out is shown in fig. 9. A standard on rollers supports the X-ray tube and the fluoroscopy screen. The screen first lies close against the patient so that a normal orientation image is obtained. After having examined this briefly and determined what part of the image requires special attention, the observer takes one or two steps to the rear drawing with him the standard with screen and tube, while the patient remains in his place. The observer can now see the part in question more clearly on the enlarged image.

One of the disadvantages for the doctor is that upon enlargement he literally loses contact with the patient. In normal fluoroscopy it is very useful to be able to turn the patient slightly and to move him about so as to make use also of the sense of touch.

When using enlargement this is not possible, because the time is too short and, moreover, the doctors' arms are not long enough to reach the patient from his position behind the more distant screen.

In spite of this the investigation gave encouraging results. From statistics of the small number of 51-cases examined 9) it was found that by enlarged fluoroscopy in the case of 10 patients better insight was obtained into the structure of a lung process, 8 times the presence or absence of a cavity was ascertained with greater security (the diagnosis was later checked with the still better photographic image) and in general in 35 cases an improvement was noted, compared with 16 cases where enlarged fluoroscopy gave no concrete advantage.

One of the practical problems still to be solved before enlarged fluoroscopy can become part of the daily practice of the röntgenologist is the adequate protection of the patient against too high doses of X-radiation. This will be more necessary, because just the difficult or interesting cases which form the most fruitful objects for enlargement technique are usually observed for a longer time even in normal fluoroscopy. And this holds even more for the screening of the abdominal organs than for that of the lungs, since in the former case, due to the greater absorption, higher radiation intensities and in some cases (stomach examinations) longer times of observation must be employed.

8) G. C. E. Burger, Hand. 29 Ned. Nat. Gen. Congres, Amsterdam 1943, p. 47. Fig. 8 is also borrowed from this.

9) G. C. E. Burger, not yet published.