AN ECONOMICAL FORM OF X-RAY CINEMATOGRAPHY

M. DENNY, *Diagnostic Radiologist, Johannesburg*

The ingenuity of research workers in the field of X-ray apparatus has presented to the profession the image intensifier and its complementary equipment devised for X-ray cinematography. Further research on their part has developed the pulsing unit for X-ray cinematography, which allows for intermittent X-ray exposure to coincide with the frame of the cine-film, thereby reducing radiation to the patient, while at the same time imposing less strain on the X-ray generator and tube. More recently the Matchlett Corporation have advertised their first stereoscopic X-ray cinematography tubes.

These developments, generally speaking, are all to the good but, since the equipment is expensive to manufacture, the outlay demanded from the radiologists is so high that the average private practice finds the initial investment beyond its means. Indeed, the cost of some of the more expensive equipment for image intensification, cinematography and television may well give rise to considerable thought in Government-financed institutions.

While a prospective buyer may be prepared to purchase an image intensifier, the superadded cost of an electronically controlled cinematography unit (about R2,700 retail) proves to be not only a deterrent to the purchase of the cinematography unit, but also of the intensifier, to which it is complementary.

Our initial installation consisted of a 9-inch Philips image intensifier with a 35-mm. Ariflex camera and cine-control and density meters. After some years' experience with this apparatus we found that variation of the light during a cine-procedure almost entirely depended on whether the screen and camera were centered over a single area of the body or moved to parts of varying density. If movement occurred from an area where tissue density was high to one where it was low, or *vice versa,* their electronically aided light control was of value. For example, where the screen was kept over a moving cervical spine a set density could be maintained throughout the examination, provided that it was of sufficient penetration to pass through the tissue under examination and so produce a diagnostic cine-film. Movement of the part in no way altered the tissue image; it merely resulted in blackening of the film beyond the confines of the anatomical part. The same is true of the heart if a pre-set density is used that will result in sufficient blackening to produce an image of the structure when filled with contrast medium. The image of the heart immediately before the injection of the medium will be darker than desired, but as soon as the dye has entered the heart a diagnostic cine-film will be produced, provided there is no significant associated movement of the overlying screen and camera. In cine-venography, on the other hand, where the screen is moved from the point of injection in either the thigh or the ankle region, a variation of radiation is required to avoid a thin or dark film respectively. In such circumstances electronic control of light density is of value; but even here a knowledge of the film used, the speed of the lens, and the thickness of the parts resolves the problem into one of simple radiographic principles. A radiographer working with this equipment very soon learns how to vary the milliamperage as the screen moves to different parts of the limb.

As such instances appear to be isolated, it occurred to us that the more elaborate X-ray cinematographic procedure could be modified in such a way that expenditure on the cine-control and the electronic control could be eliminated. It also appeared that the high cost of the Ariflex camera could be considerably modified by the purchase of a good quality product capable of producing as good results as the Ariflex. An investigation was accordingly begun to ascertain whether a more economic system adaptable to existing Philips equipment could be devised.[1] Such a modification, it was felt, should be capable of coping with all but the most specialized cardiovascular procedure.

Stevenson,[2] in his original work on cinematography, used a 35-mm. Ariflex camera, which was locked directly to a 9-inch image intensifier and was then removed by a similar unlocking procedure to allow for the television camera to replace it. Since that time television has become more commonly used, and it is irksome to be obliged to remove the television apparatus for cinematography, which must of necessity be carried out with the reflex viewer of the camera. It appears to us that an installation would be more desirable which would not only permit of ordinary television viewing, but of television viewing during the cinematography procedure, which would thus eliminate the rather awkward viewing, and the change-over of television camera to cine-camera.

THE SOLUTION OF THE PROBLEM

The Philips 9-inch image intensifier can be supplied with a turret that allows for three separate ports of viewing. The ports are allocated varying degrees of light, determined by a calibrating control mounted on the turret. On such an adaptor it is possible to have a television camera, a cine-camera, and a mirror or 70-mm. camera, on three ports.

Since it was possible, as shown by Stevenson,[2] to do without electronic light control and cine-control, it only remained to obtain a camera, and an adequate lens system, to replace the expensive Ariflex camera. The Bolex camera has already been used by the Marconi firm for the direct cinematography of the television monitor. Here, however, an elaborate phasing system to synchronize the camera and the television is required. The camera, however, is a far cheaper product than the Ariflex camera, and appears to have most of the qualities of the Ariflex camera so far as cinematography is concerned.

The 9-inch image intensifier is supplied with a double lens system that produces an infinity image. It was therefore necessary to obtain a camera lens that had the following characteristics:

1. Focal distance that would allow the full area of the frame to be covered.
2. A lens that would include the full image in this area.

3. A lens of sufficiently wide aperture not to necessitate undue radiation in order to obtain a photographic image.
4. The lens would also have to be positioned immediately adjacent to the inlet port, to avoid loss of low-density green light from the reflecting mirror of the adaptor.

The lens initially tested in this experiment was the standard lens with a focal distance of 25 mm. and a lens aperture of 1·8. Fig. 1 (A) shows that the full image of the heart and lungs normally covered by a 9-inch image intensifier is registered, but that only part of the frame is occupied. Fig. 1 (B) shows the effect of a 50-mm. lens,

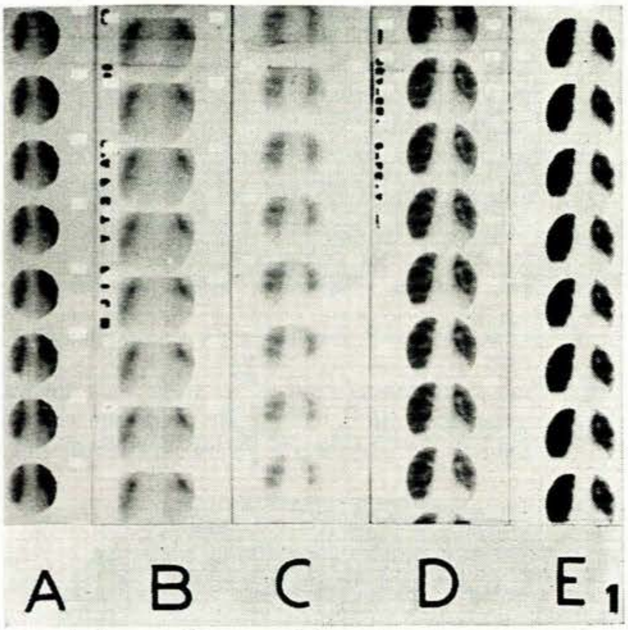

Fig. 1. Images of heart and lungs in comparative studies of lenses of varying focal distance (A 25 mm., B 50 mm., C 40 mm., D and E 35 mm.). See text. Note loss of light in B and C due to distances of 50- and 40-mm. lenses from aperture.

and here, although most of the frame area is used, part of the image is magnified, obliterating most of the heart and nearly all of the lung fields. Fig. 1 (C) shows the result obtained with a 40-mm. lens. Here, the image occupies most of the frame area but, again, owing to the magnification phenomenon only part of the heart and lungs is shown.

It was then found that no 16-mm. cine-lens was manufactured with a focal distance of between 25 and 40. Since this appeared to be the optimum lens for positioning immediately adjacent to the aperture of the adaptor port, we seemed to be faced with an insurmountable problem. Both the 40- and 50-mm. lenses had to be positioned too far from the port to obtain adequate filling of the frame, and the consequent loss of light necessitated an unwarranted increase of radiation. The 25-mm. standard lens could not be positioned near enough to fill the frame area, because the rotating-mirror system of the Philips adaptor is almost flush with the aperture of the adaptor. This mirror, during its rotation for the selection of various intensities of light for cinematography, would foul the lens if this protruded more than 1 cm. into the port area.

On further enquiries, however, a Pentax 35-mm. still-camera lens was found to be available, having the required 35-mm. focal distance. This lens could be used on a 16-mm. cine-camera, to which it could be screwed by means of an adaptor ring already retailed by the Paillard-Bolex organization. Fig. 1 (D) shows that this lens placed immediately against the aperture port fulfilled the four requirements of an adequate lens. Not only was the full area of the 16-mm. frame covered, but the full image of heart and lungs normally covered by a 9-inch intensifier was obtained. The clarity of detail was subsequently found to be of an acceptable order. The proximity of the lens to the aperture port resulted in a minimum loss of light and, although the widest aperture of the 35-mm. lens was 2·3, in achieving an image it was sufficiently wide not to necessitate an undue increase of radiation. The illustrations in Fig. 1 are merely to demonstrate the areas of the frame filled by the different lenses and the amount of image covered. Fig. 1 (D) and (E), however, are both carried out on one lens, viz. the 35-mm. still-camera lens with a 35-mm. focal distance. Fig. 1 (D) is carried out on a slower film; Fig. 1 (E) is carried out on a faster green-sensitive cine-fluorographic film, and shows increased blackening obtained with the faster film.

It therefore became apparent that by using a 35-mm. still-camera lens of the Pentax type an adequate cinematographic image could be obtained, which compared more than favourably with images obtained on already established X-ray cinematography units using the Ariflex camera.

X-ray Cinematography

The next problem that arose was the creation of an adequate circuit in the control panel to enable X-ray cinematography to be carried out. In this instance, the generator and unit to be used were of the 3-phase type with selenium rectification. It was therefore not necessary to incorporate a smoothing device to avoid the ripple and stroboscopic effect sometimes associated with 4-valve units at certain frame speeds. Also, in this particular unit—a Müller D.A. 701—there were sufficient alternative circuits to enable the Philips technicians to provide an independent radiographic circuit for X-ray cinematography. To select the X-ray cinematographic circuit it was merely necessary to turn a control lever to cine-camera, and set the timer at a maximum of 5 seconds, which automatically eliminated any restriction on timing for cine-work. It was also necessary to set the kilovoltage at the approved level for the particular part being radiographed.

It is possible to include in the electrical circuit an alternative timer that allows for protracted cinematography exposures up to 20-25 seconds. At the present time our own method is merely to use a clockwork timer, the radiographer terminating the exposure.

The attachment of the Bolex camera to the triple turret is shown in Fig. 2. The bracket B consists of two metallic plates about ¼-inch in thickness and 3 inches in width, which are bolted to an angle-piece by wing nuts. It is possible to adjust each plate in relation to the other in both the vertical and horizontal directions, in order to allow for precise positioning of the lens with regard to

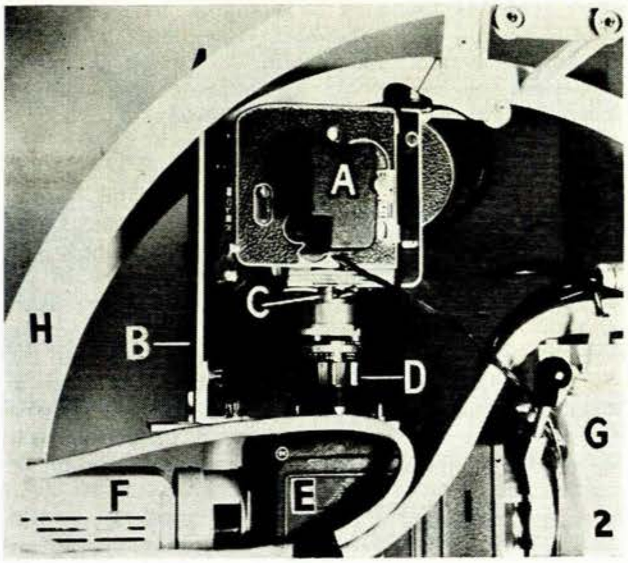

Fig. 2. Camera assembly (see text).

the image seen on the appropriate mirror of the triple turret. The base plate is likewise bolted into a linear slot that allows upward and downward movement of the camera itself. The same illustration shows the Bolex electric motor attached to the camera (A), which allows for

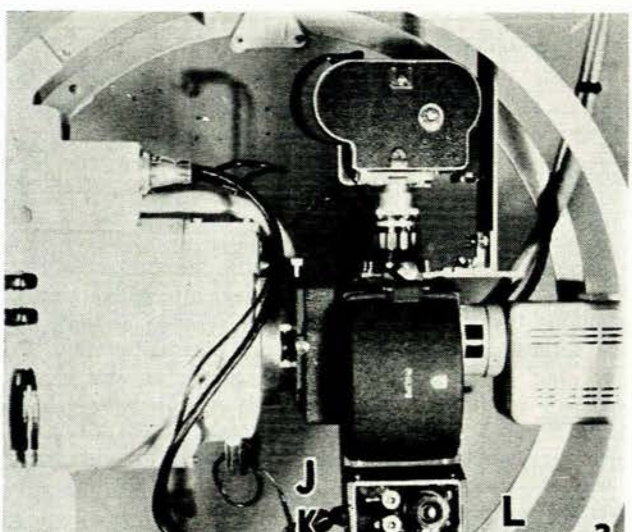

Fig. 3. Camera assembly: radiologist's side (see text).

speeds of 12, 16, 18, 24 and 32 per second. C is the adaptor piece for the 35-mm. lens, D is the 35-mm. lens itself, E is the triple adaptor showing the third and, at this time, unused port, F is the television camera, G is the 9-inch intensifier, H is the ring support that is necessary when multiple attachments to the intensifier are required, and I is the double lens system producing an infinity image for the viewing appliances. Fig. 3 shows the radiologist's side of the installation; J is the key that is depressed when the

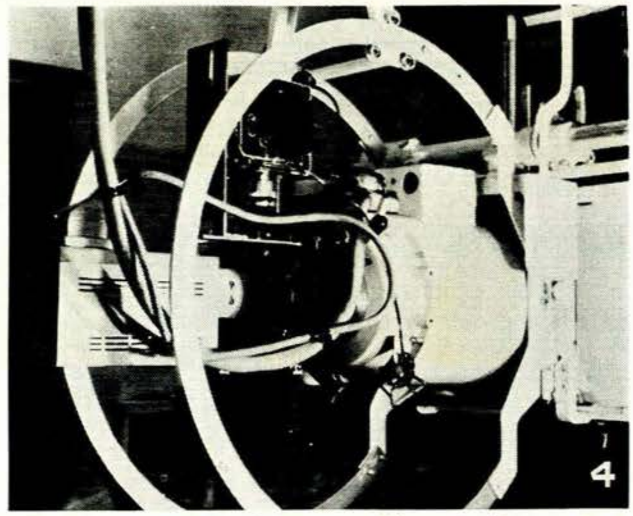

Fig. 4. General view of image amplifier, television camera and cine-camera, with 8" monitor in the background.

control knob is rotated to allow either 100% light for the television camera, or 10% light to the television camera and 90% light to the cine-camera during cineradiography;

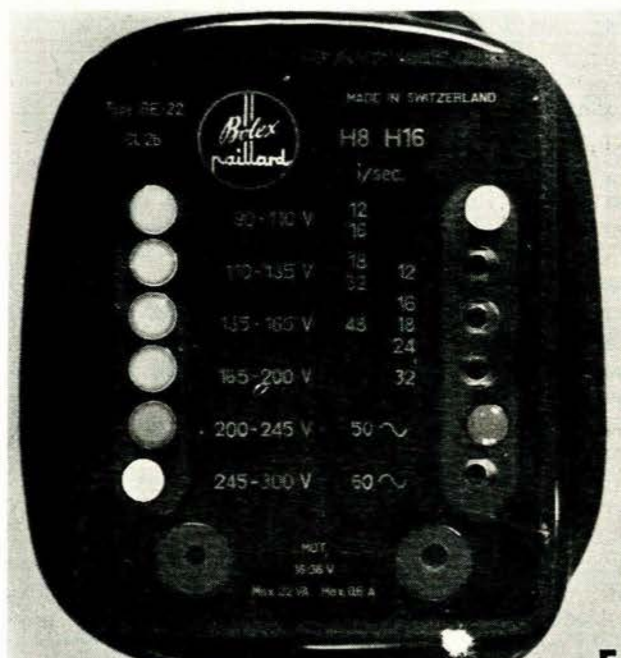

Fig. 5. Bolex transformer.

and K is the press button that activates the electric motor of the cine-camera when cinematography is commenced. Fig.

4 gives a general view of the installation. Fig. 5 shows the small transformer that is placed at the control panel and on which the frame speed can be varied from 12 to 32 by merely altering a small screw-in plug to the appropriate speed required. Fig. 6 is the rating chart for 1·2-mm. focus Philips X-ray tube for use in X-ray cinematography. This chart applies to a 3-phase selenium rectified unit.

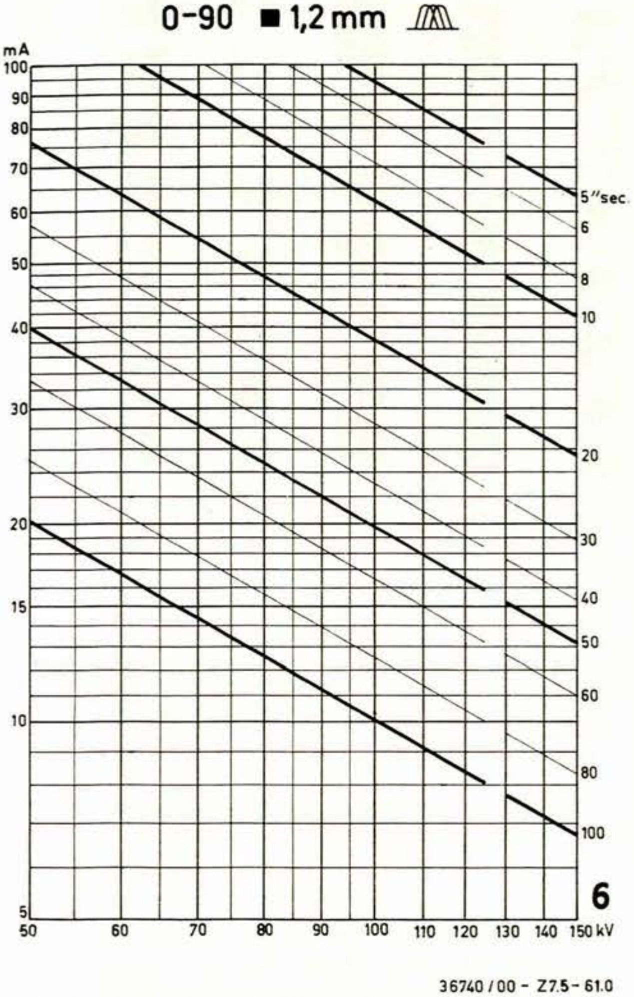

Fig. 6. Rating chart for Philips X-ray tube of 1·2 mm. focus for use in X-ray cinematography.

It shows that at the maximum factors at present used for abdominal cinematography by this unit, viz. 15 milliamps at 100 kv, the X-ray tube is capable of exposures of up to 70 seconds. The normal filming time in actual fact is made up of runs of about 15 - 20 seconds, and usually no more than 2 or 3 runs of this length.

To convert an existing X-ray control and generator to cope with X-ray cinematography of this modified nature, the unit should be of fairly modern design and must be a 4-valve rectified unit. The stroboscopic effect of a 4-valve unit will tend to occur in multiples of 50 cycles, and will therefore most often appear on the cine-films at speeds of 12½ or 25. This phenomenon is manifested by a varying blackening of the cine-film. Since it tends to occur in multiples of 50 cycles, it is possible for cinematography to be carried out on this kind of unit without the benefit of a smoothing device, provided that the multiples of 50 are avoided. To a certain extent, the phenomenon is also dependent upon the moment of starting cinematography. My suggestion is to start cinematography with the unit here described, and only if the stroboscopic effect becomes troublesome, to incorporate a smoothing unit in the circuit. It should also be possible to obtain an alternative circuit in the X-ray unit to regulate the current through the X-ray tube in such a way that the output is suitable for cinematography. Furthermore, the exposure time on the X-ray unit in the particular position in use must be such as to accommodate a cine-run. The milliamperage indication on the machine should be sufficiently sensitive to indicate the current during cinematography, in order to enable the radiographer to vary this if the screen assembly is moved over parts of different thickness. All safety devices built into the unit must stay operative as for normal work.

The range of cameras supplied by Bolex are three in number, but for this purpose the H16M without a lens is adequate, and is the cheapest of the three. The H16RX reflex allows for visual positioning of the camera so as to obtain a full image in the cine-field; but the H16M can be positioned by trial-and-error cine-runs, and can then be bolted into the correct position. The H16M model is, of course, not reflex, and can therefore only be used when an alternative viewing system such as television is employed during the cinematographic procedure. If it is intended to bolt the camera directly to the intensifier and to view through the camera, it will then be essential to obtain the H16RX camera, which enables the radiologist to view the field through the reflex viewer of the camera.

The range of X-ray factors required for various parts of the body naturally depends on the frame speed, and the following are based on the frame speed of 16; the factors must be proportionately increased for greater frame speeds:

1. Abdomen—for gastro-intestinal studies 100 kv., 10-15 ma.
2. Heart—for calcification, 100 kv., 10-15 ma.
3. Cervical spine—70 kv., 7 ma.
4. Thighs—for venography, 80 kv., 10 ma.
5. Knee region, 70 kv., 6 ma.
6. Lower leg and ankle, 70 kv. 3-5 ma.
7. Cervical area—for barium swallow, 70 kv., 7 ma.

(Tube focus 1·2 mm.)

Fig. 7 shows reproductions of cine-studies of various lesions carried out by the described method.

The outlay for an X-ray image intensification unit, together with X-ray cinematography and television, is considerable. The cost of the cinematography unit without the image intensifier and television, which are common to both, is in the range of R2,700. This covers a 16- or 35-mm. Ariflex camera and the cine-control, which includes the density meter and camera supply. The alternative method of cinematography, as suggested in this paper, costs R360. This sum includes the H16M Bolex camera without lens, the electric motor to drive the camera, the transformer to vary the speeds of the electric motor, the Pentax 35-mm. lens, the adaptor to fit this lens to the

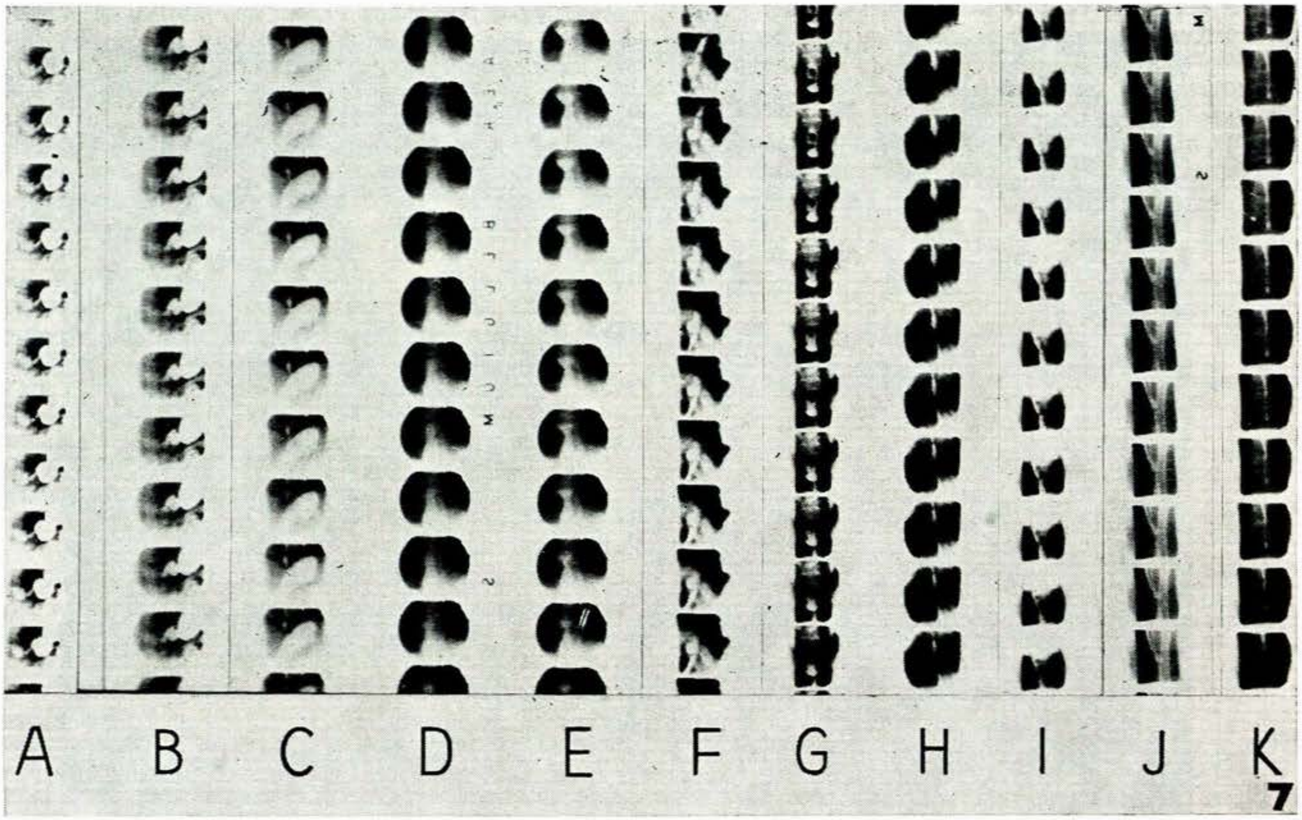

Fig. 7. 16-mm. reproductions of cine-studies carried out by the described method. A - B: contracted pyloric antrum (A) with peristaltic activity shown in B, excluding infiltration. C: small hiatus hernia with associated reflux. D - E: varying and abortive oesophageal peristalsis in a case of achalasia of the cardia. F - G: antero-posterior and lateral studies showing a posterior pharyngeal diverticulum. H - I: lateral and antero-posterior barium-swallow studies showing use of the right lateral food channel only, in a case of laryngeal palsy. J. an incompetent mid-femoral valve during erect retrograde venography. K: the same case as J, showing a competent popliteal valve.

camera, and the angled bracket to position the camera against the triple turret.

Should the radiologist's intensifier be one with a single viewing mirror which uses a turret with a single port, he will also have to obtain the triple turret system, which is supplied by Philips and costs R390. This triple turret system, of course, is common to both the established Philips and the suggested cinematography systems.

The saving, therefore, on cinematography installation where the radiologist has a triple turret in his possession is in the vicinity of R2,340, a not inconsiderable sum.

The use of 16-mm. X-ray cinematography rather than 35-mm. also appreciably reduces the cost of this method of examination, since the projection of 16-mm. film, apart from the lower cost of the film, is far more inexpensive than the projection of 35-mm. films. A Specto or Kodak analyser 16-mm. projector costs about R200 as opposed to the R1,800 of an editing table of the calibre of the Philips unit. It has been stated constantly, and also proved, that condensation of a 9-inch image into a 35-mm. frame produces a better detail than condensation of a 9-inch image into a 16-mm. frame. My own impression is that this may well be so on metallic phantoms, but that, for the human body, it is extremely difficult to detect any significant differences between the projected image, whether 16- or 35-mm. cinematography has been used.

SUMMARY

X-ray cinematography is a valuable development of diagnostic radiology, but hitherto the cost of the necessary plant has been so great that the average radiological practice finds it beyond its means, and it may well give rise to considerable thought even in Government-financed institutions.

As the result of his investigations the author reports on satisfactory X-ray cinematography achieved with an apparatus that can be installed at a cost which results in a saving in the neighbourhood of R2,340 or R1,950 according to what apparatus the radiologist already has in his possession.

I wish to thank Messrs. Beitz and Sanders, of S.A. Philips Ltd., for their interest and help in surmounting problems encountered in this study.

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