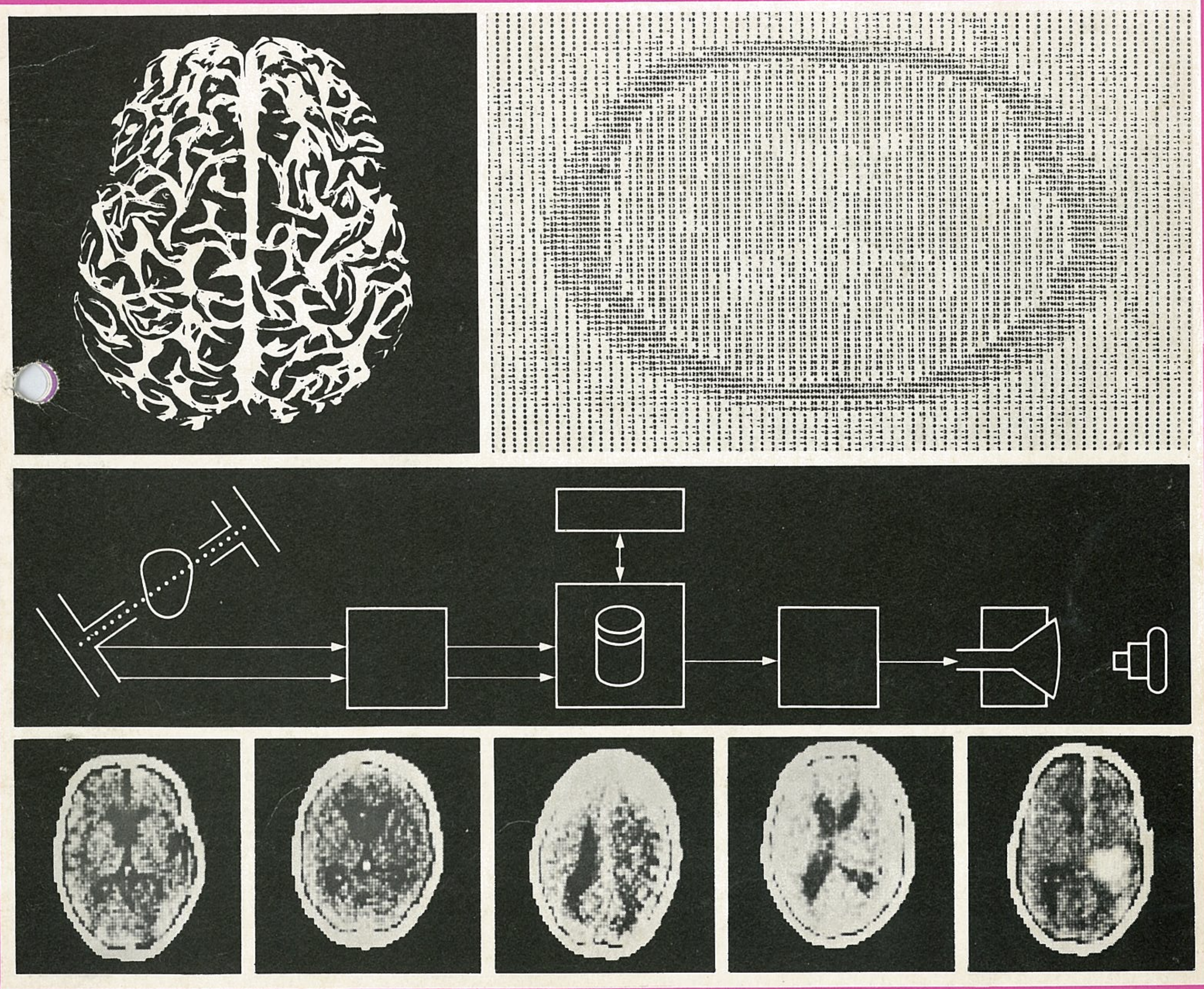
EMI-SCANNER

A new perspective on brain disease

EMI



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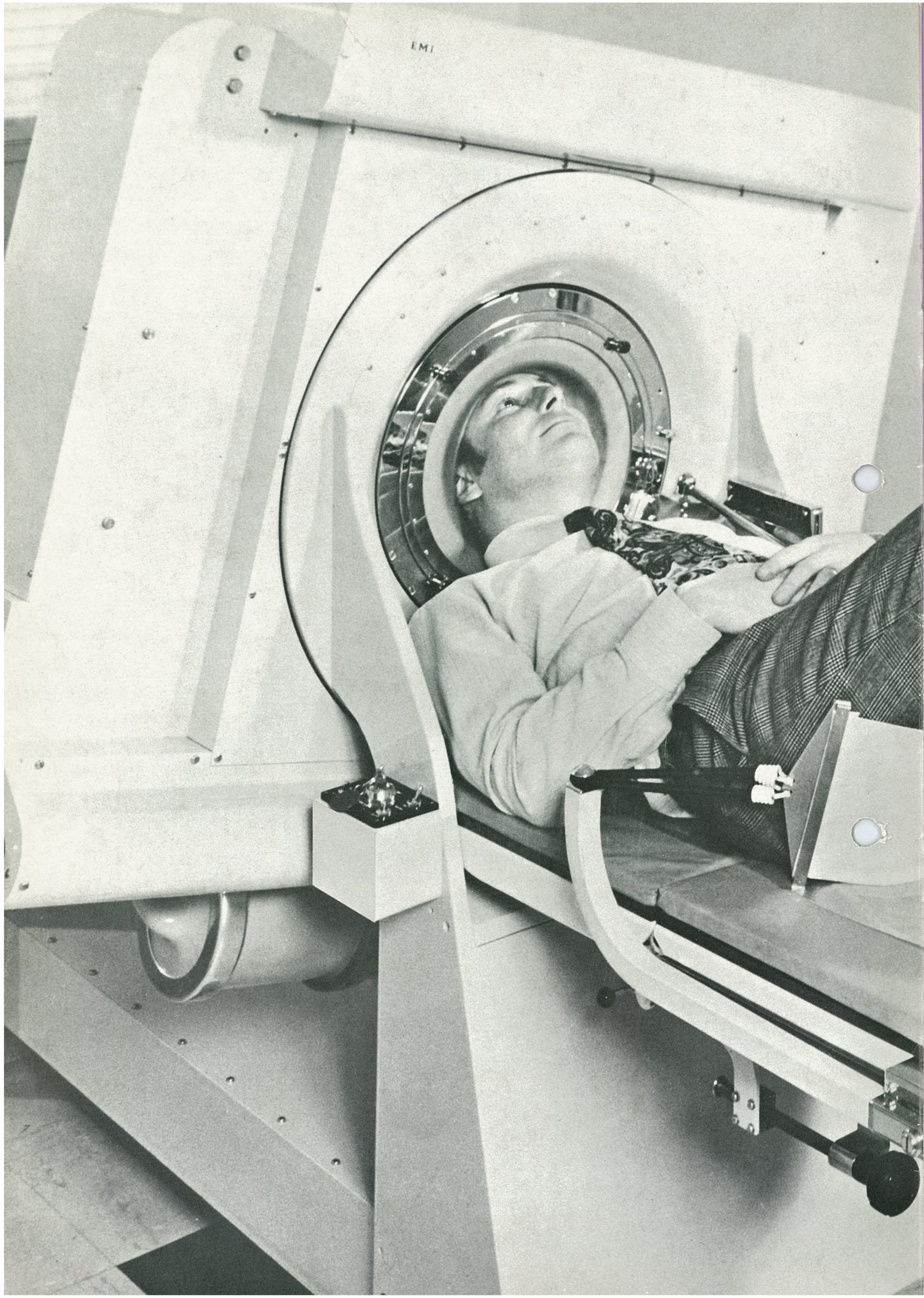
Telephone: 01-573 3888 Extension 599

EMI

1972 MacRobert Award
EMI Limited and the designer of the EMI–SCANNER system have received the 1972 MacRobert Award, for outstanding technological achievement.

1973

The Queen's Award to Industry
For technological innovation in the EMI–SCANNER, the Queen's Award to Industry was conferred on EMI Limited in 1973.



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Left
The EMI-SCANNER installed at the Department of Neuroradiology at the Atkinson Morley's Hospital—which contains the Neurological and Neurosurgical Units of St. George's Hospital, Wimbledon, England.

EMI-SCANNER

The key features of the EMI-SCANNER system in the investigation of brain tissues are:-

1. 100 times more information on brain tissue is obtained than from conventional X-ray systems
2. Straightforward operation by one unaided radiographer
3. A typical investigation consisting of three scans of the patient may be performed in about 30 minutes
4. Discomfort to the patient during investigation is avoided
5. Residual morbidity is eliminated
6. Results of investigations are available within a few minutes of the scan
7. X-ray absorption measured on tissue to an accuracy of $\pm\frac{1}{2}\%$ standard deviation on a scale -500 to $+500$

A new perspective on brain disease

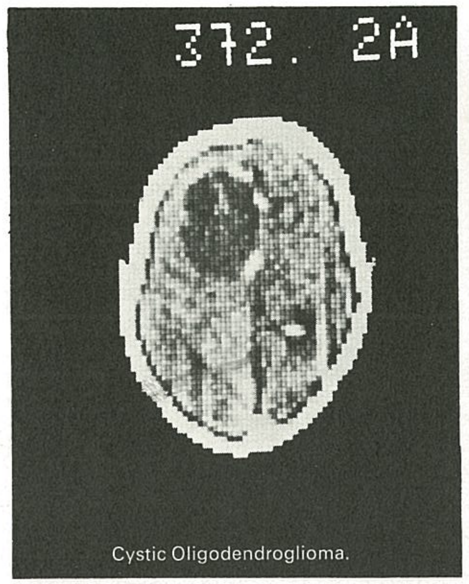
The photographs of brain tissue abnormalities shown below were produced using a new system of transverse axial tomography developed by EMI Limited in conjunction with Britain's Department of Health & Social Security.

It has been developed to permit considerably greater information to be extracted from the transmission of X-ray photons through the head, and to present the information obtained in the most useful form for evaluation by neuroradiologists, neurologists and neurosurgeons.

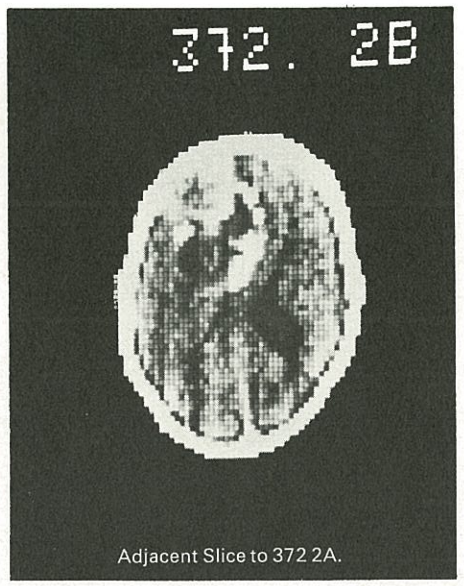
In clinical terms, the most important contribution resulting from this development is the presentation of detailed information on brain tissue abnormalities in a new perspective so that not only is accurate indication given of the nature of the lesion, but also its location within the head is defined with considerable precision in three dimensions.

The EMI-SCANNER system, which has undergone prolonged clinical evaluation, has demonstrated the facility for discriminating between tissues of minutely varying density and for eliminating many of the causes of patient discomfort and morbidity, normally associated with brain investigations using pneumography, angiography and radio-active isotope scanning.

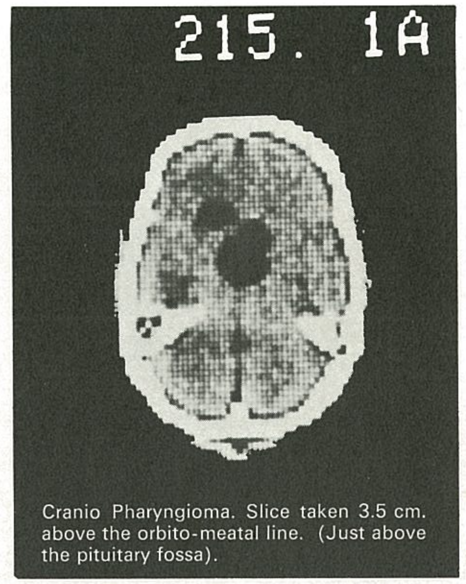
It has also shown that, by avoiding the need for anaesthesia or the injection of radio-opaque liquids, or gases, significant economies are possible. Typically an investigation consisting of three scans can be carried out by a radiographer, unaided, in about 30 minutes. These economies are achieved particularly by avoiding the need to involve medical specialists in the initial examination and eliminating the subsequent recovery period in hospital.



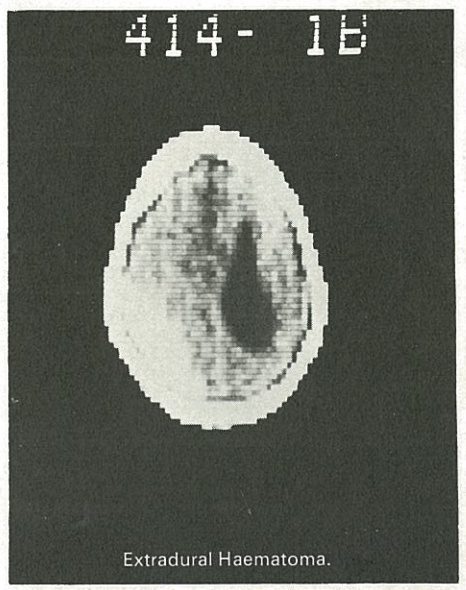
Cystic Oligodendroglioma.



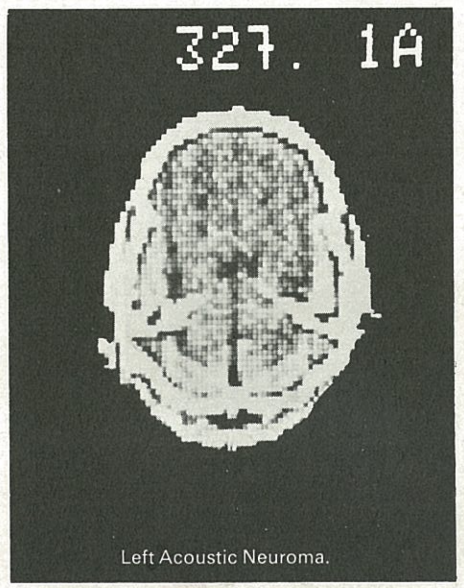
Adjacent Slice to 372 2A.



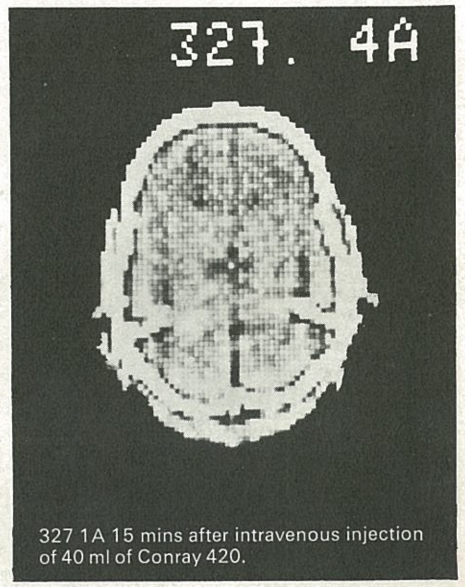
Cranio Pharyngioma. Slice taken 3.5 cm. above the orbito-meatal line. (Just above the pituitary fossa).



Extradural Haematoma.



Left Acoustic Neuroma.

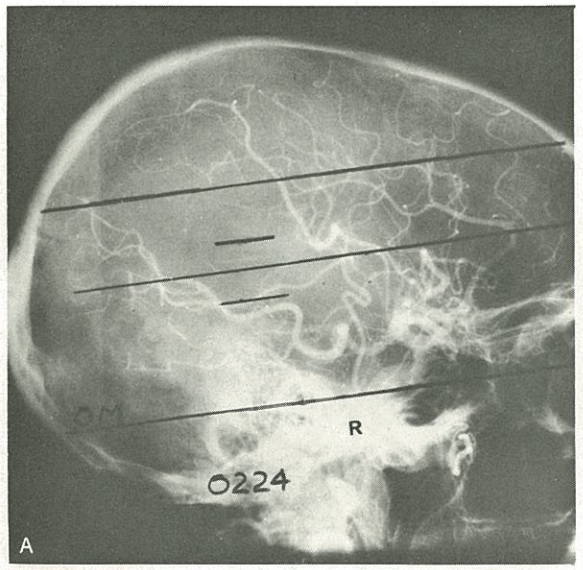


327 1A 15 mins after intravenous injection of 40 ml of Conray 420.

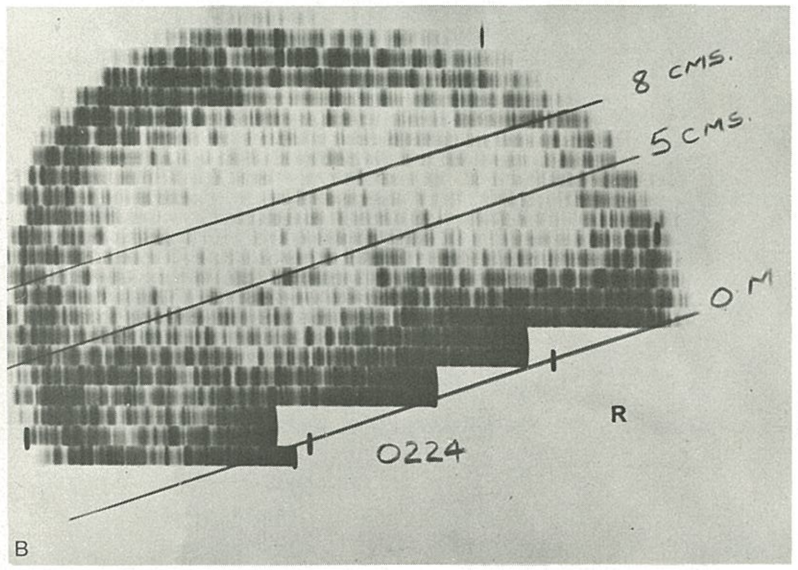
Comparative results

These illustrations compare the results by existing procedures with EMI-SCANNER investigation of a patient with a Primary Intracerebral Haemorrhage.

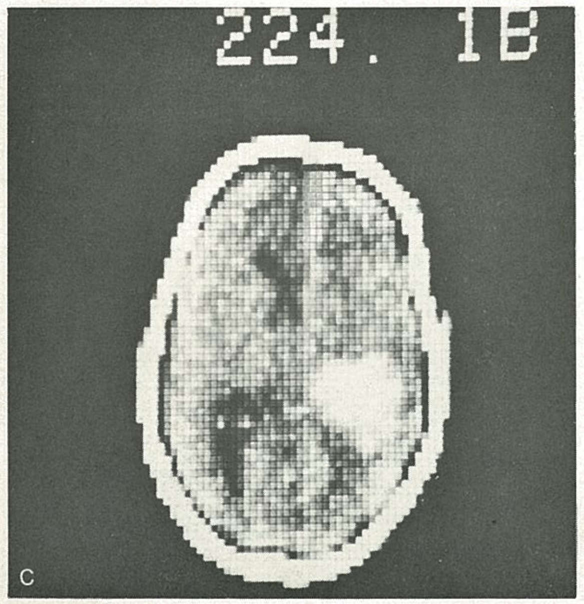
A Lateral Arteriogram
B Radioisotope Scan
C EMI-SCANNER record of a slice between 5.0cm and 6.3cm above the orbito-meatal line
D EMI-SCANNER Print out obtained from the Line Printer Unit



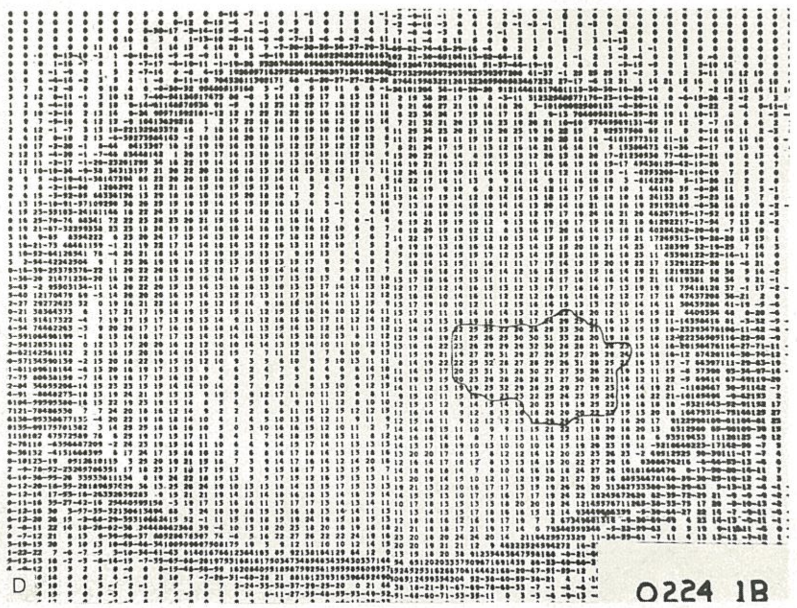
A



B



C



D

Theory of the EMI-SCANNER system

Investigations have indicated that with conventional X-ray techniques, approximately 99% of the information released by the transmission of X-ray photons through the head is not realised in a useful form on the photographic plate. This information loss is, of course, due to the difficulty of discriminating between tissues of closely similar photon absorption coefficients, together with confusion resulting from the super-imposition of three-dimensional information on a two-dimensional record.

Since all soft tissues fall within the narrow band of only approximately 4% overall variation in absorption coefficient (Figure 1), discriminating between different tissue densities within this band demands the use of extremely sensitive detectors.

Further, to avoid superimposition, and hence confusion of the details in the resulting record, it is necessary to employ tomographic principles, to allow the three-dimensional object to be examined as a series of two-dimensional slices (Figure 2).

The EMI-SCANNER combines the use of sensitive photon detectors with tomographic examination techniques. These are used in conjunction with a computer to handle the vastly increased amount of information which is retrieved. Although the X-ray dose is comparable with a conventional skull radiograph, the system uses the X-ray photons more efficiently to yield approximately 100 times more information on brain tissue than alternative methods and is consequently able to present information on marginally varying densities of tissue across the full area of each tomographic slice.

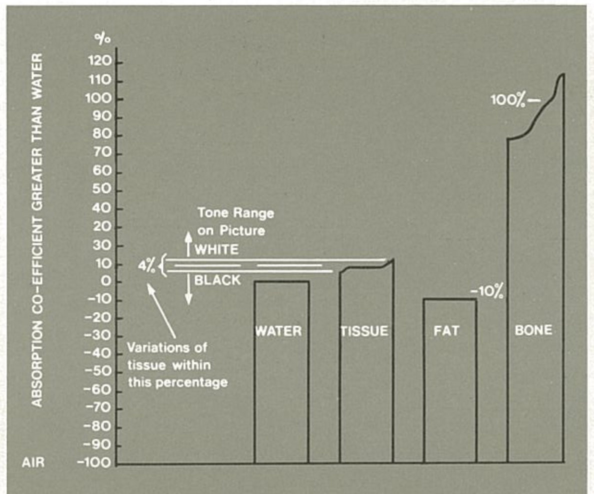


Figure 1

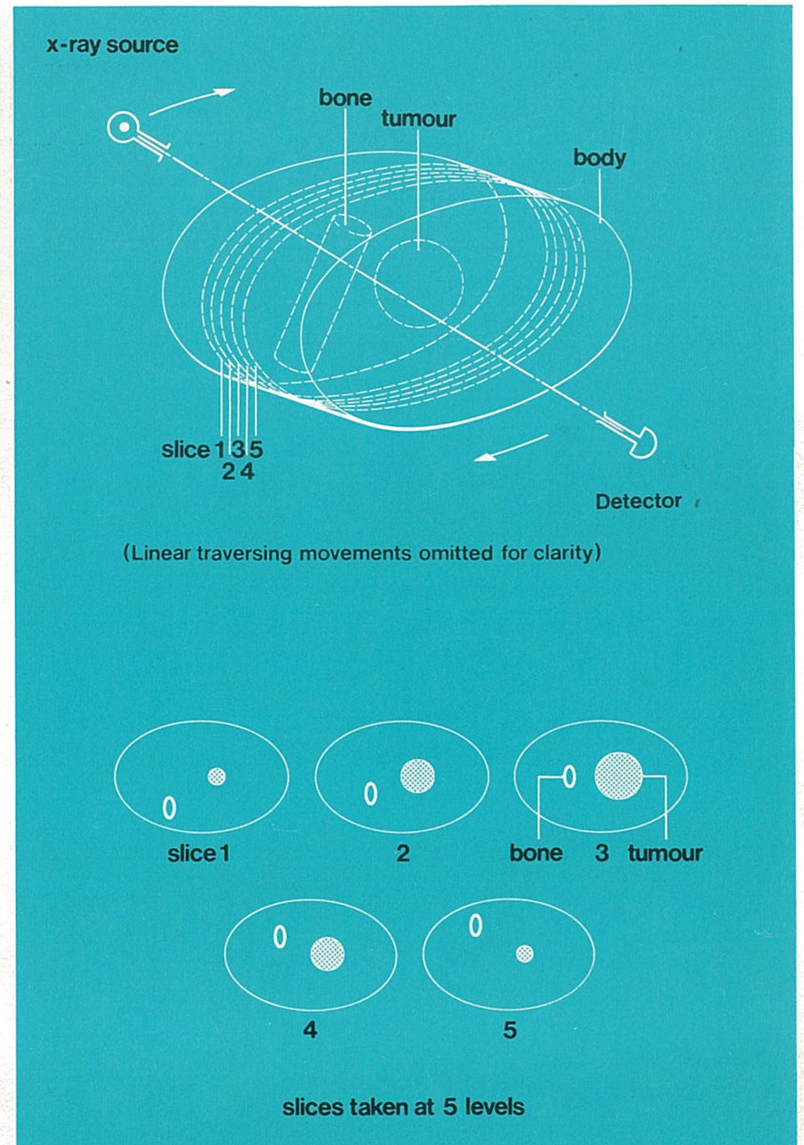
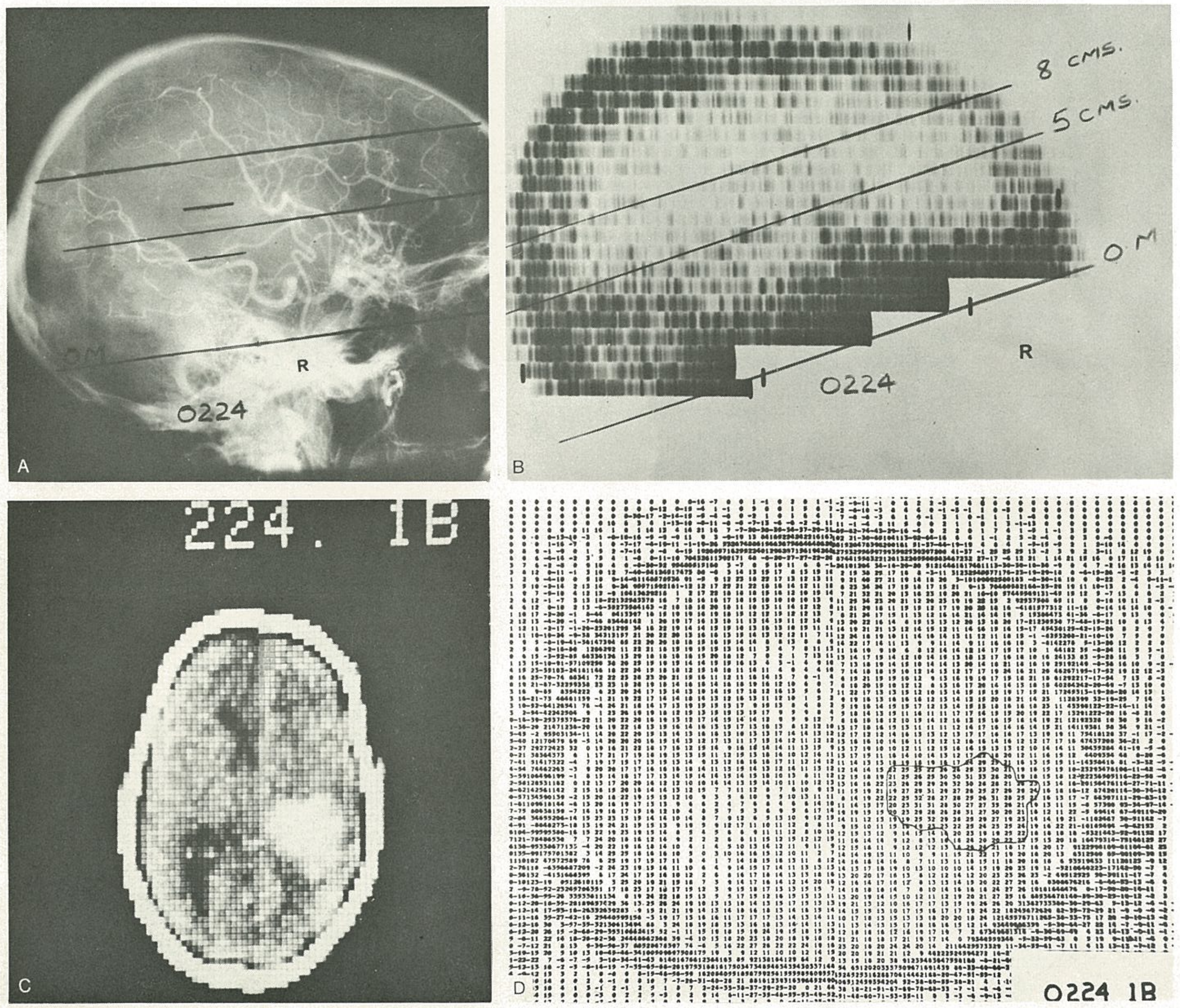


Figure 2

Comparative results

These illustrations compare the results by existing procedures with EMI-SCANNER investigation of a patient with a Primary Intracerebral Haemorrhage.

- A Lateral Arteriogram
- B Radioisotope Scan
- C EMI-SCANNER record of a slice between 5.0cm and 6.3cm above the orbito-meatal line
- D EMI-SCANNER Print out obtained from the Line Printer Unit



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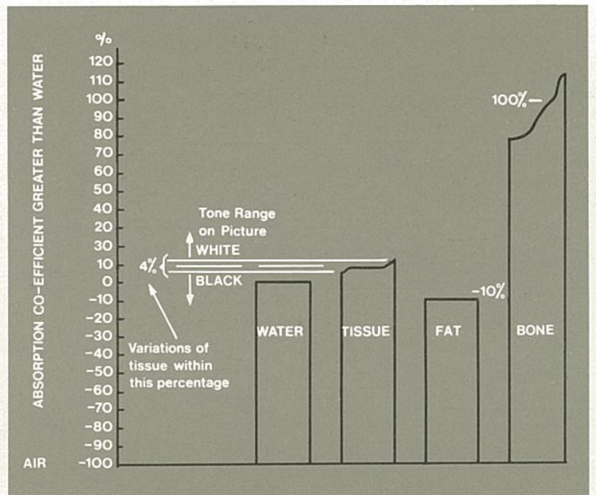


Figure 1

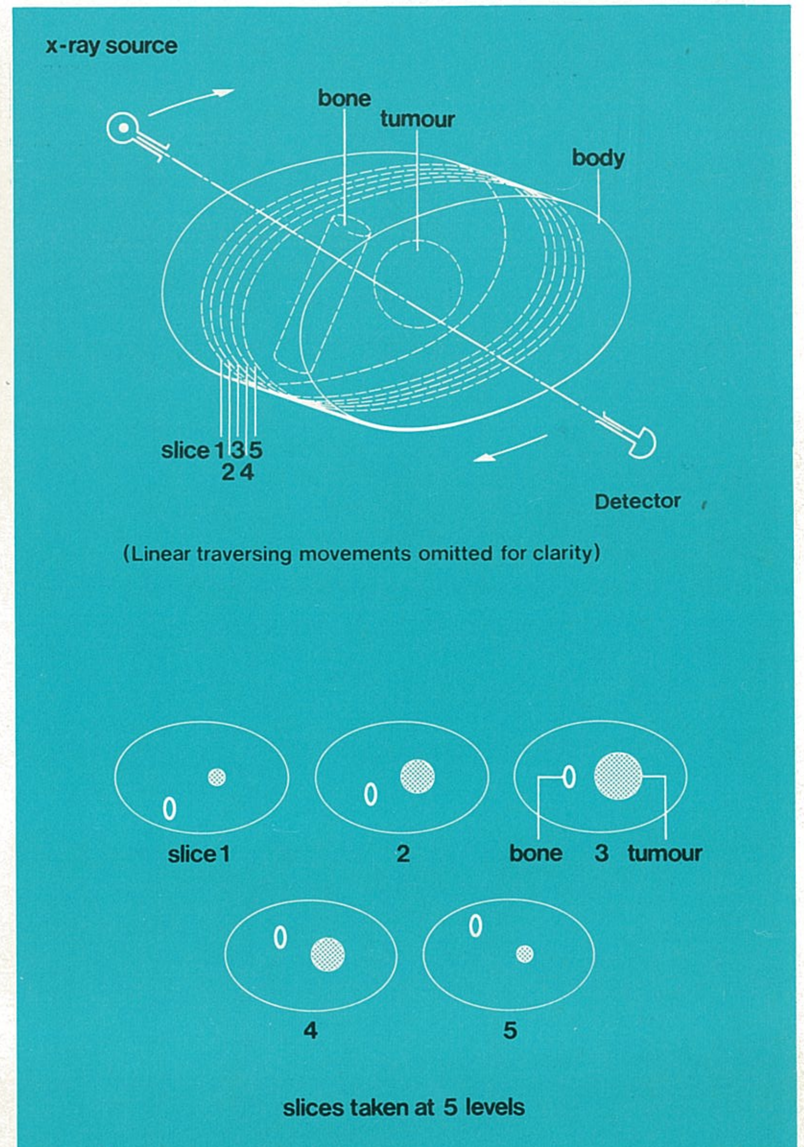


Figure 2

Operation of the system

The EMI-SCANNER system consists of a scanner unit (housing an X-ray source and accurately aligned detector units), a control unit, a computer unit, a viewing unit, a printer unit and a teletype (Figure 3). The system also includes the X-ray generating units.

The equipment uses a narrow beam of X-rays to scan the patient's head in a series of either 0.8cm or 1.3cm wide slices; two adjacent slices may be taken simultaneously in the span of about five minutes. The rays are passed through the head and are detected by two sensing devices which always remain in alignment with the X-ray source. Both the X-ray tube and the detectors traverse across the patient's head linearly taking 160 readings of transmissions through the head as shown on the diagram (Figure 4).

The X-ray scanning unit is then rotated 1° around the head and the process is repeated (Figure 4). This continues for 180 scans, when 28,800 readings will have been taken by each detector. These readings are then processed by a mini-computer which calculates 6,400 absorption values of the material within each slice from the 28,800 simultaneous equations generated.

The system yields about one hundred times more information on brain tissue than conventional X-ray systems and enables small variations in tissue density to be differentiated. The skin area irradiated is confined to a narrow band around the edge of the slice and the dosage is approximately equivalent to a conventional X-ray picture.

From the calculations performed by the computer, a picture may be built up in the form of a matrix (80x80) of 6,400 picture points, each indicating the value of the absorption coefficient of the corresponding material at each point in the slice. This matrix is displayed on the cathode ray tube screen of the viewing unit and is also output as a numerical print out (Figure 6) of the absorption coefficients by the line printer unit. This provides detailed information about the nature of the tissue and is a function of the density and atomic number of the material.

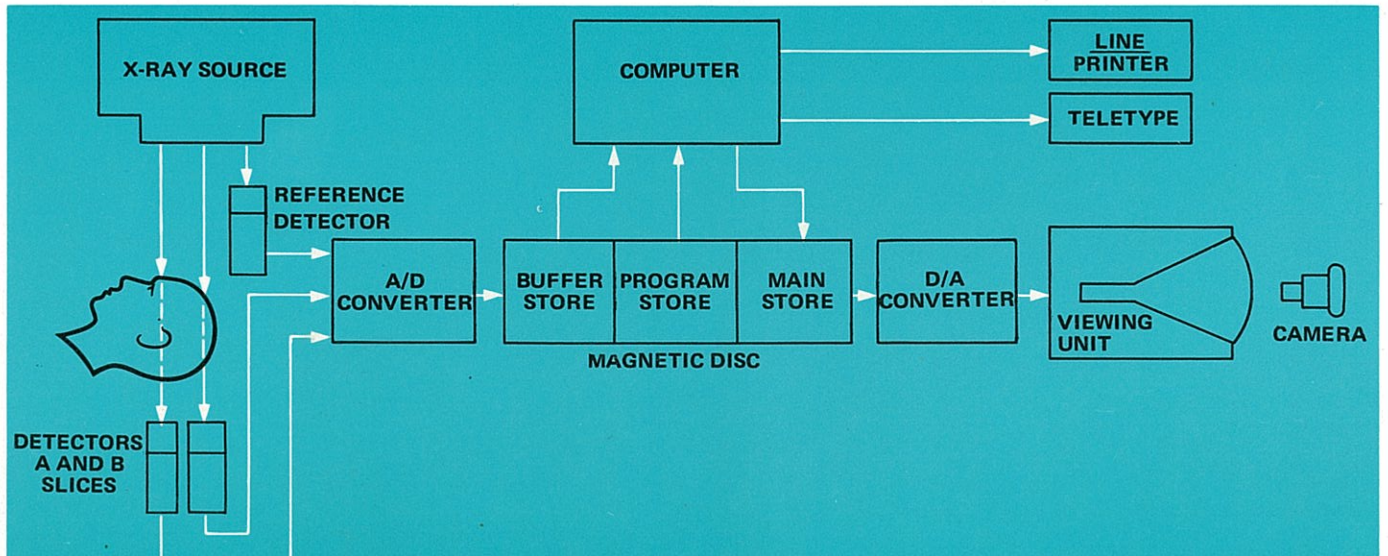


Figure 3

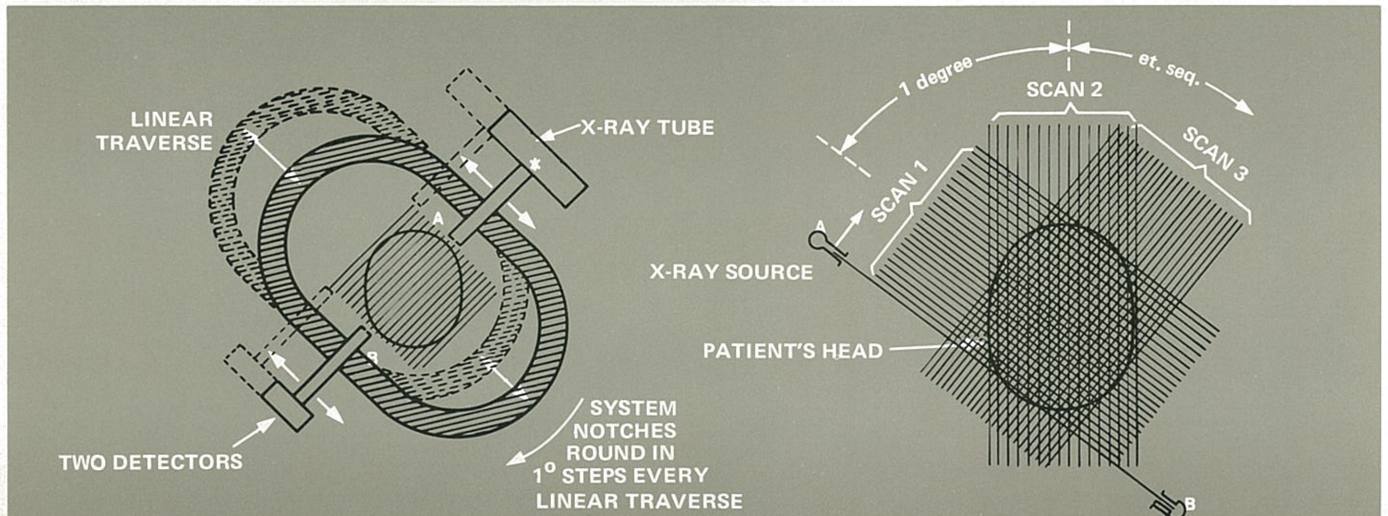


Figure 4

Some idea of the range of measurement of the system can be demonstrated by the chart (Figure 5) which shows the absorption values for a number of materials commonly encountered in clinical radiology. These values are established on an arbitrary scale used in the system where air is −500 and water is 0. It can be seen that on this scale the value for Fat is −50, whereas the value for tissue found in the head varies between +12 for white matter to +18 for grey matter.

The system sensitivity can be selected by means of the 'window width' switch which selects the range of absorption values which yields black to peak white on the c.r.t. display. This control has 7 settings: 100, 75, 50, 40, 30, 20, and 'Measure'. A further calibrated control 'window level' enables the centre of the range selected by the 'window width' switch to be set at any desired point on the system scale, i.e. between −500 and +500. This control is adjusted to suit the material under examination. Thus for tissue examination the 'window level' control would be set at about +15 whereas for examination of fat the control would be set at −50 in order to obtain the best display.

The 'measure' setting of the window width switch, which yields 1 digit between black and white on the display, can be used to measure the absorption value of any point. The window level control is adjusted until this point just changes from black to white on the display; the absorption value can then be read directly from the scale on the window level control.

In operation the equipment is straight-forward and an unaided radiographer can perform an examination consisting of 3 scans in about 30 minutes. The patient lies on the examination table with the head in a rubber head-cap in the scanner unit. It will be seen (Figure 7) the patient is able to wear normal clothing and the position of examination is

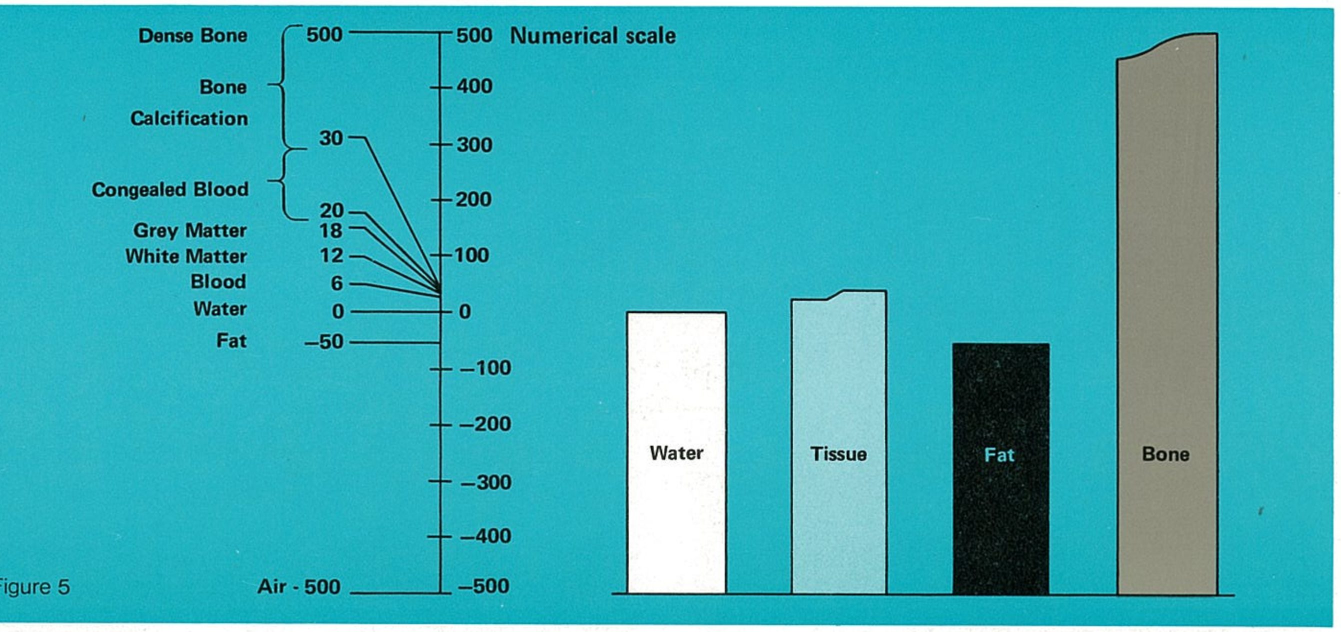


Figure 5

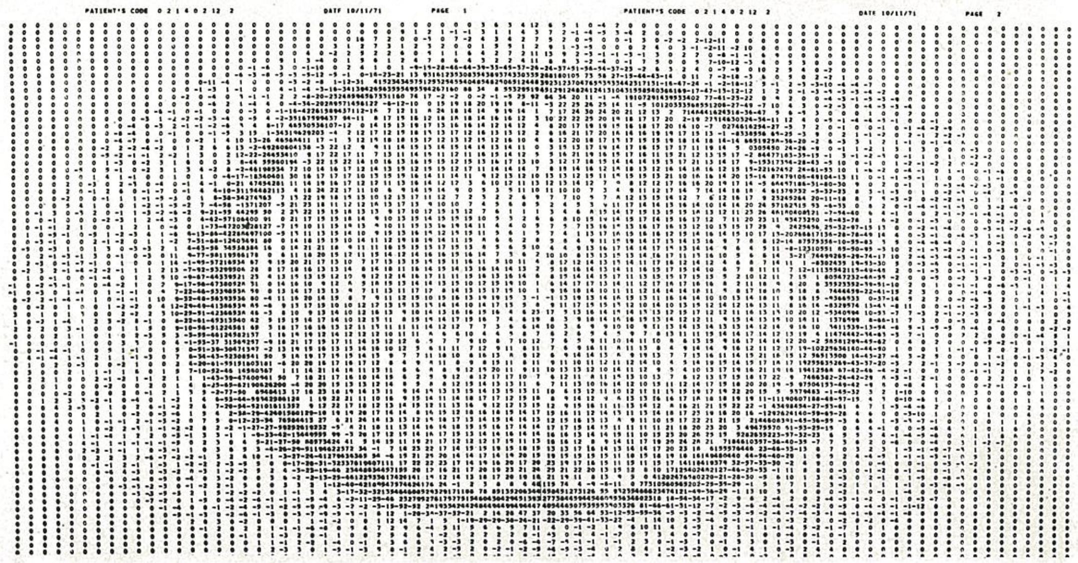


Figure 6

such that the patient is comfortable and relaxed. This permits considerable benefits, since the distress and possible hospitalisation resulting from conventional methods are completely eliminated.

The radiographer operates the scanner from the control unit in the protective cubicle as shown in the photograph (Figure 9). Simple controls are provided and a number of interlock arrangements ensure safe operation.

The results from scans are stored in a removable magnetic disc store. The readings from the previous X-ray investigation may be processed by the computer while the subsequent patient is being scanned. The computer takes approximately 5 minutes to perform the calculations required for each picture and the processed results are then stored on the magnetic disc for subsequent viewing, photography and analysis. The viewing unit is shown in the illustration (Figure 8). The results of a number of scans are illustrated in the photographs (Figure 10). All these results are displayed on the 80x80 matrix.

The smallest volume that can be detected would have an area viewed perpendicular to the slice of approximately 3mmx3mm the other dimension being the width of the slice which can be varied between 1.3 cm to 0.8 cm. As a general guide to diagnosis the computer print-out and the chart (Figures 5 and 6) should be studied. A single high number at least ten units above or below the rating of the surrounding tissue could indicate an abnormality but numbers with lower variation must be considered in groups covering larger areas.


Figure 7

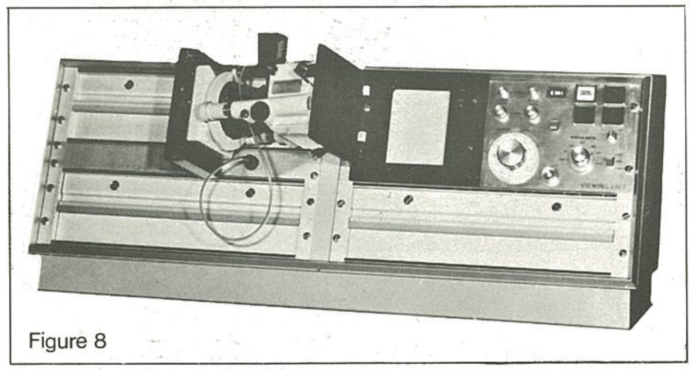


Figure 8

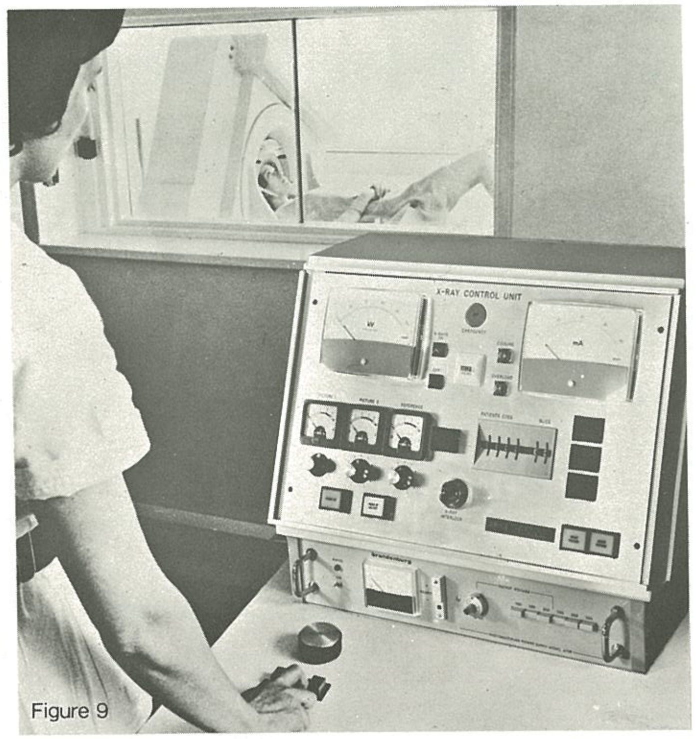


Figure 9

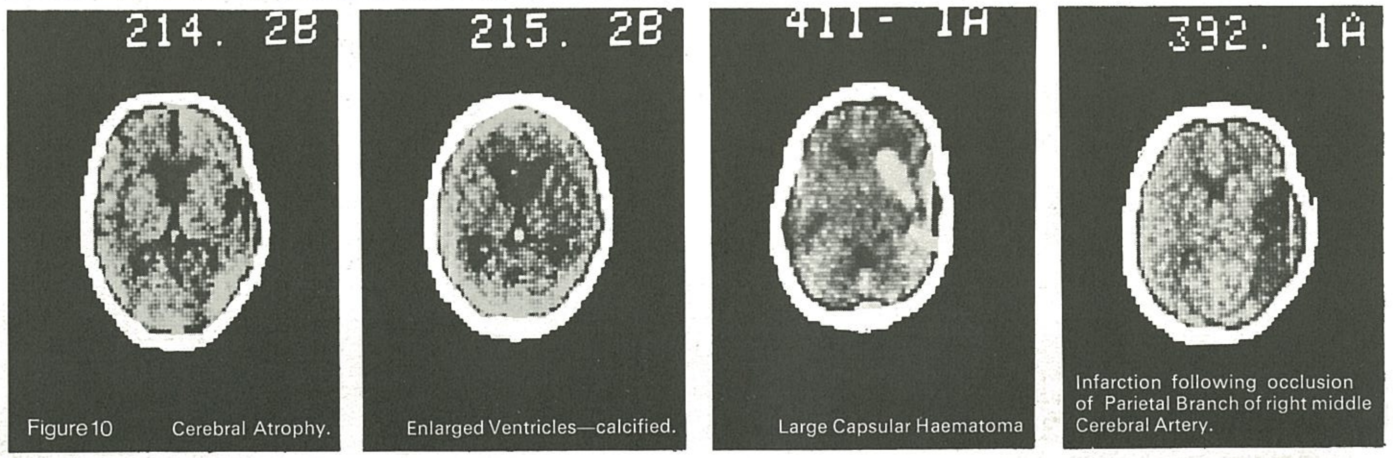


Figure 10 Cerebral Atrophy. Enlarged Ventricles—calcified. Large Capsular Haematoma. Infarction following occlusion of Parietal Branch of right middle Cerebral Artery.

Radiation Dosage to the Patient

Since the X-ray source moves around the head in a 180° arc the skin dose is not the same for all points around the head. Fig. 11 shows the isodose contours obtained using a water filled phantom, and it can be seen that the right hand side of the head receives the highest skin dose.

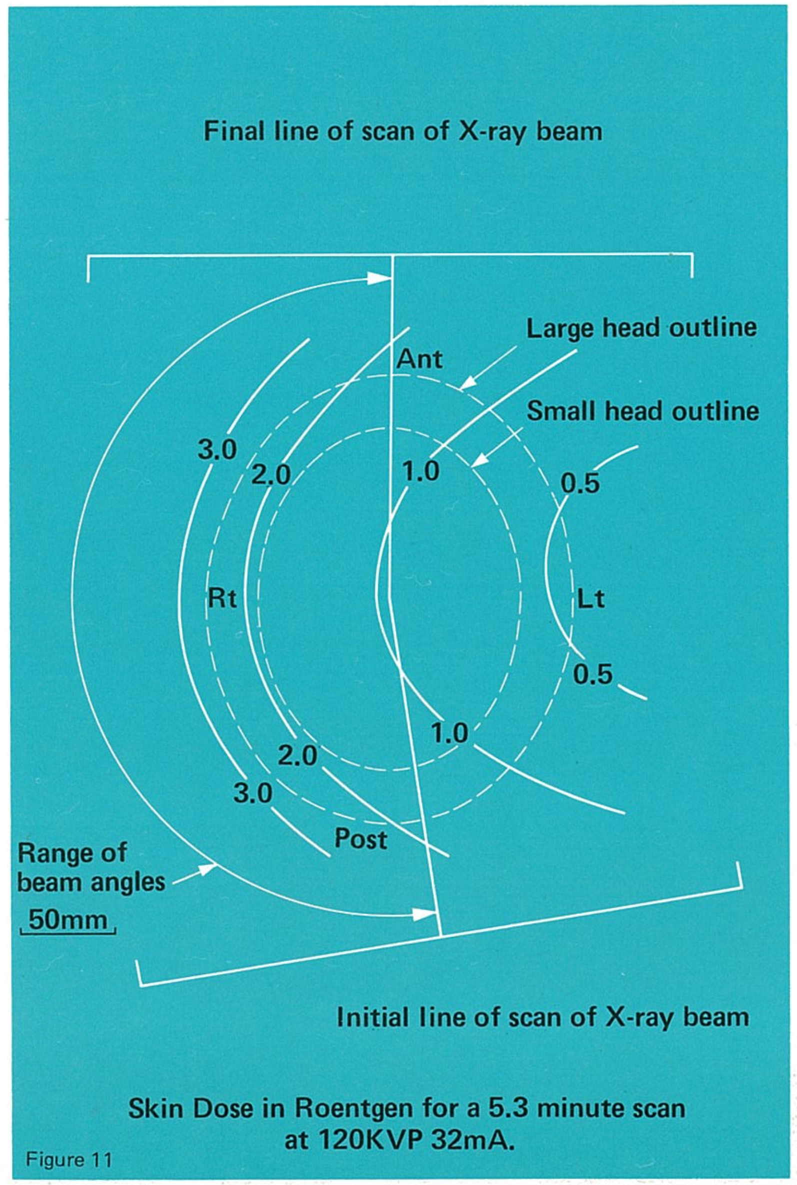
During each scan, only the strip of skin around the head corresponding to the two sections examined receives radiation and *not* the whole head as in a conventional skull radiograph. Therefore if a number of successive scans are so arranged that they do not overlap, the skin dose is not compounded.

The internal dose is at all points less than the maximum skin dose.

Head Location

For most normal examinations the head of the patient is held in a conical head support and the orbito-meatal line is parallel to the front ring of the machine thus ensuring that the sections examined are also parallel to this line. See Fig. 12.

For examinations low on the back of the head the conical head support can be easily removed and a cylindrical one replaced. The use of this cylindrical head support enables the head to be tilted so that areas such as the posterior fossa may be examined. This is shown in Fig. 13.



Skin Dose in Roentgen for a 5.3 minute scan at 120KVP 32mA.

Figure 11

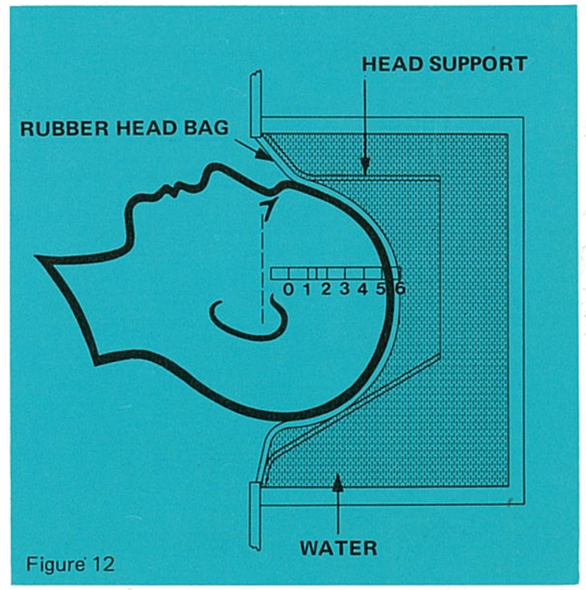


Figure 12

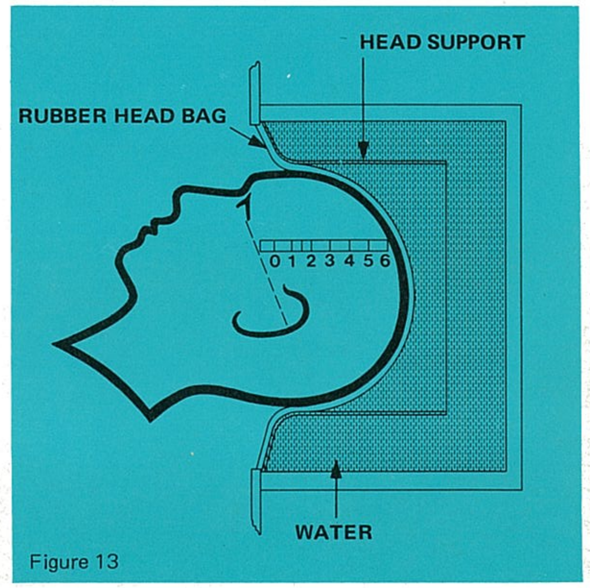
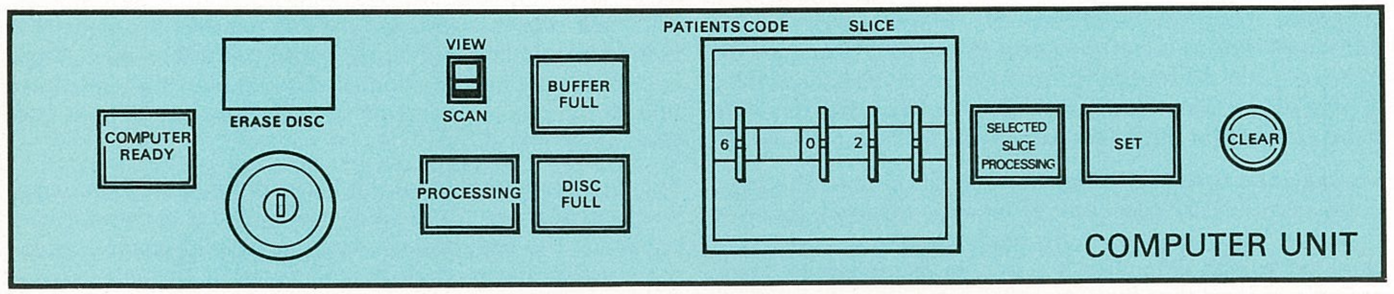
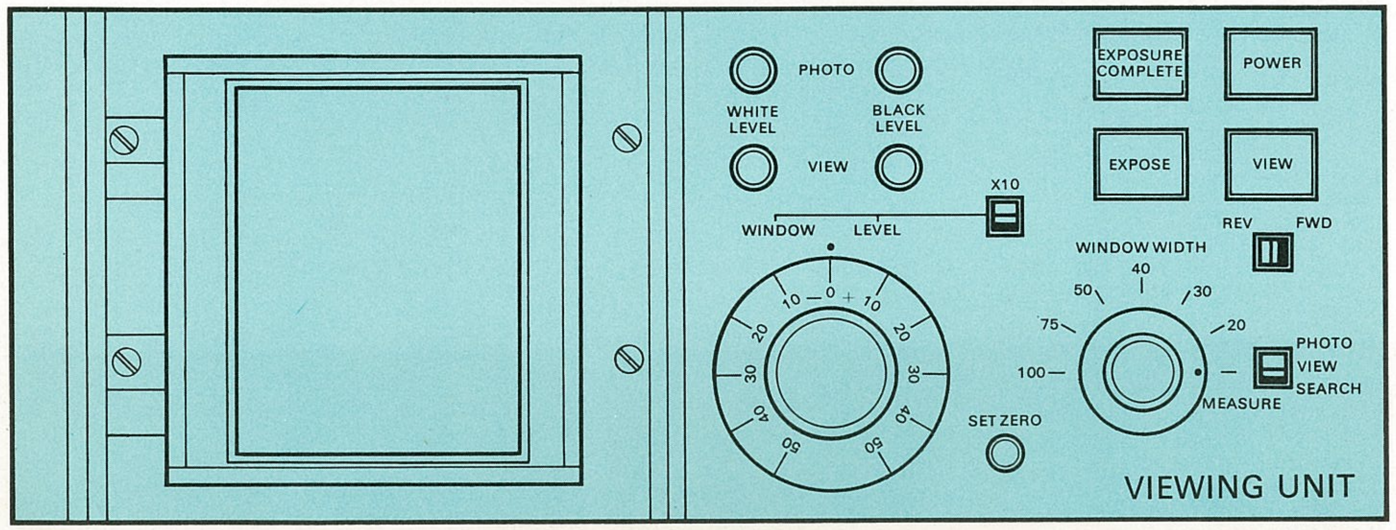
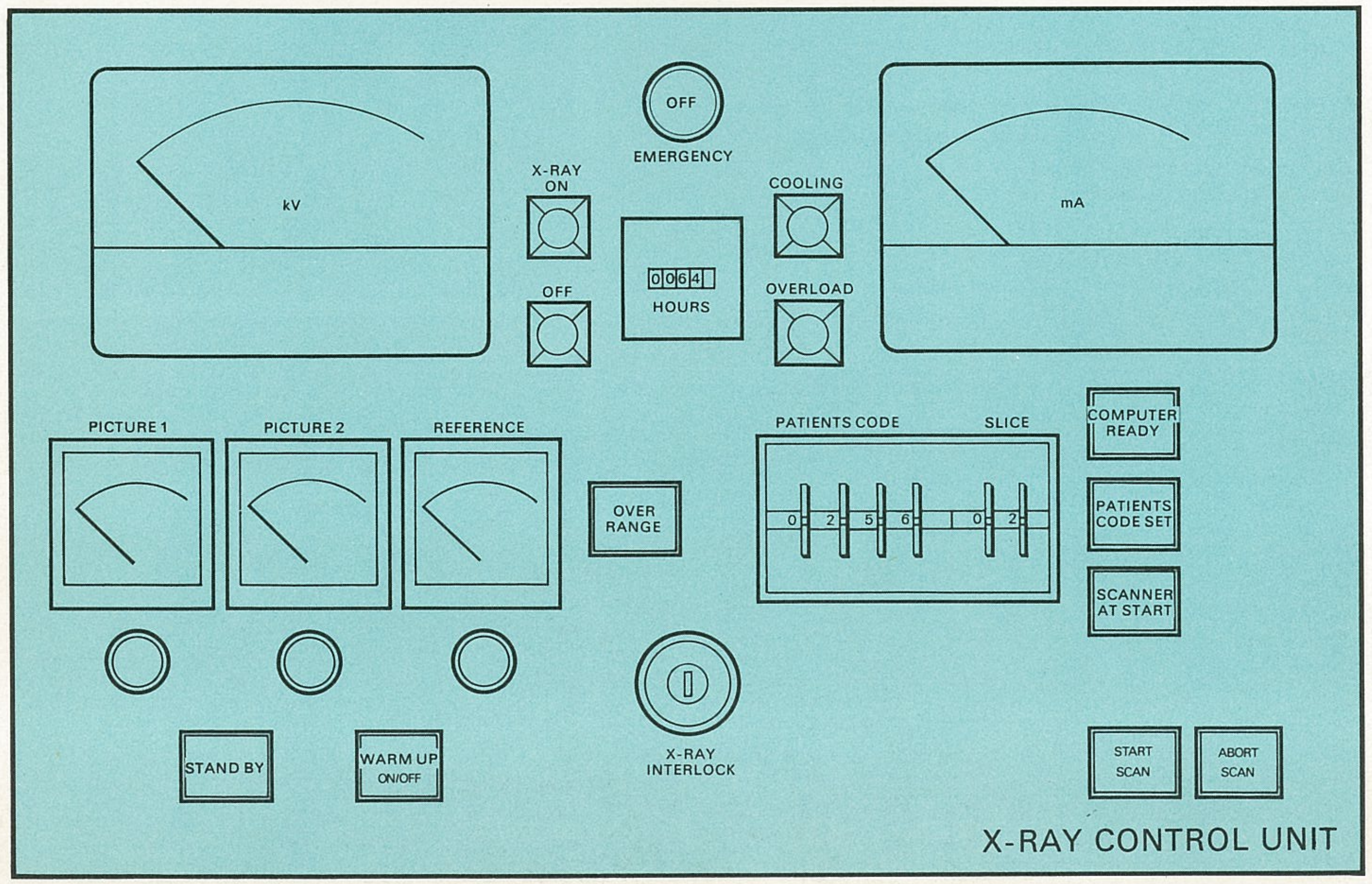


Figure 13

Control panels







Specifications

Capability:
To be capable of simultaneously scanning two contiguous sections through a live human head and processing the readings taken to give a picture display on a viewing unit, and a computer print-out of the absorption values.

Range of X-ray absorption coefficient:
+500 to −500 (see the scale used on Figure 5)

Accuracy of X-ray absorption measurement at 120kV:
±½% standard deviation measured on water
For a scale −500 to +500, i.e. ±2½ digits
(For practical purposes the accuracy for tissue and water is the same).

Resolution of X-ray absorption value:
1 digit on the scale −500 to +500

Time of single scan (2 contiguous sections):
Variable in steps between approx. 4½-20 minutes.

Radiation Dosage to the skin for a complete head examination of 3 or 4 scans each of 5.5 minutes duration:
120kV – Mean dose 1.25R Maximum dose 1.91R
140kV – Mean dose 1.55R Maximum dose 2.26R

Radiation Dosage to the skin for a complete head examination of 3 or 4 scans each of 4.5 minutes duration:
120kV – Mean dose 1.02R Maximum dose 1.57R
140kV – Mean dose 1.27R Maximum dose 1.85R

Gonad Dose for a complete scan:
Less than 0.1mR.

X-ray tube Voltage/Current:
100kV – 40mA max.
120kV – 33mA max.
140kV – 28mA max.

X-ray tube focal spot size:
12 mm × 2.25 mm nominal.

Mean X-ray beam width:
0.8 cm or 1.3 cm per slice

Detectors:
Sodium iodide crystals + photomultipliers

Rubber head cap life:
Up to three months depending upon use

Power requirements:
The system can be made to operate from a range of voltages at either 50 or 60 Hz.
Requirements: Three phase 7kVA together with single phase 4kW

Water supply to oil cooler:
To be capable of supplying a maximum flow of 4 imp./pints/minute (2.3 litres/minute)

Initial warm-up time of X-ray tube:
15 minutes

Operating temperature range:
10°C – 35°C

X-ray tube leakage:
Less than 10 mR per hour at 1 metre from the tube (excluding scatter from patient)

Computation Time:
Approximately 5 minutes per picture

Storage disc capacity:
About 60 pictures

Picture Matrix:
80 × 80

Display Size:
Rectangular 140 mm × 101 mm (5½ inches × 4 inches)

Refresh rate:
1 frame per ¾ second

Reference number display:
The picture reference number appears above the X-ray picture on the C.R.T. and shows the patient's number and slice number.
A and B represent lower and upper slice respectively.

Camera:
Polaroid Print size 76 mm × 95 mm (3 inches × 3¾ inches)

Sizes

Scanning Unit

Minimum Length required including space for table movement and equipment door opening:
393.4 cm (155 in)

Minimum Height required for rotation:
175.2 cm (69 in)

Minimum Width required for rotation:
152.4 cm (60 in)

Weight:
Approx. 914 kg (2010 lb)

Maximum Floor Loading:
1.69 kg/sq cm (24 lb/sq in)

Viewing Unit

Maximum Width:
108.9 cm (42.87 in)

Maximum Height:
117.6 cm (46.31 in)

Maximum Depth including Desk:
68.6 cm (27 in)

Weight:
Approx. 159 kg (350 lb)

X-ray Control Unit

Width:
61.2 cm (24.13 in)

Height:
117.6 cm (46.31 in)

Depth:
68.6 cm (27 in)

Weight:
Approx. 204 kg (450 lb)

Computer Cabinet Unit

Width:
57.8 cm (22.75 in)

Height:
190.4 cm (75 in)

Depth (Cabinet)
64.8 cm (25.5 in)

Depth (cabinet including plinth):
74.1 cm (29.13 in)

Depth (overall):
74.9 cm (29.5 in)

Weight:
Approx. 272 kg (600 lb)