MODERN TRENDS

IN

DIAGNOSTIC RADIOLOGY

(SECOND SERIES)

Edited by

J. W. McLaren

M.A., M.R.C.P., F.F.R., D.M.R.E.

RADIOLOGIST, X-RAY DEPARTMENT, ST. THOMAS'S HOSPITAL, LONDON; SOMETIME EXAMINER IN RADIOLOGY, UNIVERSITY OF LONDON

BUTTERWORTH & CO. (PUBLISHERS) LTD.

LONDON

1953

INTRODUCTION

IT is five years since the previous series of Modern Trends in Diagnostic Radiology appeared, and since then great advances in this branch of medicine have been made. In the preface to the first series it was pointed out that the whole field of diagnostic radiology was not covered, and this series supplements the first by including many aspects of diagnostic radiology which were not previously included. The aspects of radiological diagnosis presented in this series are quite different, with the exception of a revised article on cerebral angiography, and a chapter on the medico-legal aspects of radiology which has been brought up to date in the light of changes in hospital administration and services brought about by the National Health Service.

As in the first series, the articles are by authors of international repute, and again I should like to point out that the views put forward are the responsibility of the authors concerned.

The articles have been written by radiologists in many countries, and therefore the style must vary considerably with the author. The meaning of a particular author, often originally expressed in his own language, has been kept to as closely as possible in the translation. This has been done purposely to avoid any alteration of emphasis or intent.

Many of the subjects dealt with in this series are still undergoing rapid advancement. Apparatus is being steadily developed and techniques are continually improving. Bearing this in mind many of the opinions expressed by authors may be altered quite quickly in the light of fresh knowledge.

The first and second series should be read in conjunction with each other, because there is little overlapping of subjects in the two books.

My thanks are due to all the contributors for their willing help and co-operation, to my Secretary, Miss Anderson, for her patience in helping to prepare this book, and to Messrs. Butterworths for their help in publication.

May, 1953. J. W. McLAREN.

TABLE OF CONTENTS

INTRODUCTION – – – – – – – – – – – xi

CHAPTER PAGE

1. DESIGN IN RADIOLOGICAL APPARATUS – – – – – – 1
Georg Schonander, Georg Schonander, Ltd., Stockholm
Georg Fredzell, Laboratory Chief Engineer, Georg Schonander, Ltd.
and
Poul Busch, Research Laboratories, Georg Schonander, Ltd.

2. SIMULTANEOUS MULTISECTION RADIOGRAPHY – – – – 15
W. Watson, F.S.R., Ilford, Ltd., London

3. PROTECTION IN DIAGNOSTIC RADIOLOGY – – – – – 26
W. V. Mayneord, D.Sc., F.Int.P., Professor of Physics Applied to Medicine, University of London

4. VOLUME DOSES IN DIAGNOSTIC RADIOLOGY – – – – – – 35
J. Feddema, M.D., Radiologist, Medical Department, Philips Factories, Eindhoven, Holland
and
W. J. Oosterkamp, M.A., Senior Physicist, Philips Research Laboratories, Eindhoven, Holland

5. RADIOLOGY IN RESEARCH – – – – – – – – – 43
G. M. Ardran, M.D., D.M.R., Radiologist, Nuffield Institute for Medical Research, Oxford

6. PULMONARY MANIFESTATIONS OF FUNGOUS DISEASES – – – 53
J. W. Pierce, M.D., M.R.C.P., D.M.R.D., Radiologist to St. Thomas's Hospital and The Brompton Hospital for Diseases of the Chest

7. DIAGNOSTIC EVOLUTION OF THE HEART DYNAMICS BY ANGIOCARDIOGRAPHY – – – – – – – – – – – 90
Carl Wegelius, M.D., and John Lind, M.D., the Department for Cardiovascular Research of the Wenner-Gren Institute at Norrtulls Hospital and the Paediatric Clinic of the Caroline Institute, Stockholm

8. SELECTIVE ANGIOCARDIOGRAPHY AND THORACIC AORTOGRAPHY – 114
Gunnar Johnsson, M.D., Radiologist at Sodersjukhuset, Stockholm, Sweden

TABLE OF CONTENTS

CHAPTER PAGE

9. SMALL INTESTINE - - - - - - - - - - - 145
J. W. McLaren, M.A., M.R.C.P., F.F.R., D.M.R.E., Radiologist, X-ray Department, St. Thomas's Hospital, London ; Sometime Examiner in Radiology, University of London
and
J. M. French, Phys.D., M.D., D.T.M.H., Research Fellow, Department of Pharmacology, University of Birmingham

10. RADIOGRAPHY OF THE COLON - - - - - - - - - 158
Arthur C. Singleton, M.B.E., M.D., F.R.C.P. (C), F.F.R., F.A.C.R., Associate Professor of Radiology, University of Toronto ; Senior Radiologist, Toronto General Hospital ; Consultant Radiologist, R.C.A.F.

11. RADIOLOGY IN ACUTE ABDOMINAL DISEASES - - - - 178
J. Frimann-Dahl, M.D., Sc.D., Director, Roentgen Department, Ullevaal Hospital, Oslo

12. THE RENAL TRACT - - - - - - - - - - - 203
Nils P. G. Edling, M.D., Radiologist, Roentgen Department, Karolinska Sjukhuset, Stockholm

13. BACKFLOW IN EXCRETION UROGRAPHY DURING RENAL COLIC - 214
Olle Olsson, M.D., Professor of Diagnostic Radiology, University Clinics, Lund, Sweden

14. RADIOLOGY OF THE PANCREAS - - - - - - - - 218
R. A. Kemp Harper, M.B., F.R.C.P.E., F.R.F.P.S., M.R.C.P., D.R., Director, X-ray Department, St. Bartholomew's Hospital, London

15. RADIOLOGY OF MUSCLES, SKIN AND SUBCUTANEOUS TISSUE - - 239
Arne Frantzell, M.D., Associate Professor of Diagnostic Radiology, Upsala University, Sweden

16. ARTHROGRAPHY - - - - - - - - - - - 251
K. Lindblom, M.D., Professor of Diagnostic Roentgenology, Stockholm

17. ANKYLOSING SPONDYLITIS AND THE SACRO-ILIAC JOINTS - - 267
Folke Knutsson, M.D., Professor of Diagnostic Radiology to the University Clinic, Upsala, Sweden

18. THE SYNDROME OF PROTRUSION OF CERVICAL INTERVERTEBRAL DISCS 277
Hugh Davies, T.D., M.A., D.M., D.M.R.E., Radiologist, National Hospital, Queen's Square, London

19. AIR STUDIES OF THE SKULL - - - - - - - - 291
E. Lindgren, M.D., Professor of Roentgenology, The Caroline Institute ; Director Roentgen Department, Serafimer Lasarettet, Stockholm

TABLE OF CONTENTS

CHAPTER		PAGE
20.	CEREBRAL ANGIOGRAPHY – – – – – – – – – –	313
	Arne Engeset, M.D., Neuro-Radiologist, University Hospital of Oslo, and the Roentgen-Radium Institute, Oslo and Kristian Kristiansen, M.D., Neuro-Surgeon, Ullevaal Hospital, Oslo	
21.	LUMBAR AORTOGRAPHY – – – – – – – – –	341
	E. Lindgren, M.D., Professor of Roentgenology, The Caroline Institute ; Director, Roentgen Department, Serafimer Lasarettet, Stockholm	
22.	MYELOGRAPHY – – – – – – – – – – – –	355
	R. Reid, V.R.D., M.B., Ch.B., F.F.R., Radiologist, Manchester Royal Infirmary, Manchester and G. K. Tutton, M.B., Ch.B., F.R.C.S., Lecturer in Neurosurgery, University of Manchester	
23.	HYSTEROGRAPHY IN CANCER OF THE UTERUS – – – –	373
	Olof Norman, M.D., Associate Professor of Diagnostic Radiology, University Clinics, Lund, Sweden	
24.	THE LAW RELATING TO THE PRACTICE OF RADIOLOGY – –	382
	Walter Montague Levitt, M.D., F.R.C.P., F.F.R., D.M.R.E., Barrister-at-Law and The late Denis Frank Townshend, Barrister-at-Law, London	
INDEX	– – – – – – – – – – – – – –	395

CHAPTER 1

DESIGN IN RADIOLOGICAL APPARATUS

GEORG SCHÖNANDER, GEORG FREDZELL, AND POUL BUSCH

AS RADIOLOGY is a young science, it is only natural that its progress should be rapid. It is in the last decade that notable advances in construction and elaboration in methods have been made. This is due to an increasing collaboration in scientific development and greatly improved team work between physicists and radiologists. International collaboration has developed immensely, while radiologists of different nationalities do, of course, tend to keep to their own techniques. This collaboration now tends to guarantee the same level in design and production of radiological devices in all civilized countries.

The general principles of design in apparatus during recent years are partly a fulfilment of the just demands of radiologists to simplify their work, and give improved protection against radiation and to obtain better function of their apparatus, and also the incorporation of new development in electronics and adjacent technical fields.

Besides these commendable general principles, special interest has been paid to the use of kilovoltages higher than 100 kVp as applied to diagnostic radiology, not only to obtain shorter exposure times, but also as an expansion of the diagnostic possibilities in conjunction with increased use of radio-opaque solutions. The possibility of utilizing high diagnostic kilovoltage is, however, above all a question of the power of secondary grids, as the scattered radiation is highly increased.

The interest in studying the dynamics of the human organs has likewise intensified the work in serial radiography and ciné-radiography. The lack of tradition in this field ensures rather novel ideas in the design of new apparatus, but unfortunately the result of this is that much produced today does not fulfil all the requirements of versatility.

The following summary is chosen in order to exemplify at least the major improvements made in recent years, though it is not complete in any way. The apparatus mentioned is to be considered exemplary of several equally significant ones of the same standard. Furthermore, the authors are aware of the fact that there may be more advanced units on the market, which may be quite unknown to them.

EXAMINATION STANDS

Universal tilting tables

The motor-driven tilting table, commonly used for conventional x-ray examinations and often the only examination stand of small hospitals and clinics, has during recent years been the object of various improvements.

Counterweights are in the modern types of tables substituted by counter-balancing spring systems that largely facilitate the examining work, as the weights which have to be accelerated may be reduced to approximately half their former value. In some of the newest types even motors are being used for the moving of the fluorescent screen, as well as for the cassette carriage. The tables are furthermore designed so that this carriage may be slid down to the off-side of the table when not required. This facilitates the positioning of the patient and is an advantage for over-couch radiography. The supports and driving mechanism are concealed behind side panels which are flush with the upper edge of the table. It is thus possible for the operator to stand closely to the edge along the entire length of the table. The panels afford space for the operator's feet and fully screen off the scattered radiation of the under-couch tube. The supporting column of the over-couch tube is rigidly guided in floor-rails and ceiling-rails and may be coupled to the built-in Potter-Bucky diaphragm. Operating handles for the adjustment of the table are conveniently placed and the brakes are as a rule of the electro-magnetic type. Some tables may be tilted to any position between vertical and 45 degrees Trendelenburg by means of a special double pivoting system and the construction often eliminates ceiling suspensions for the auxiliary devices.

Spot film devices

The serial changers, practically always used in connexion with the motor-driven tilting table, have also improved during recent years and one of the latest models

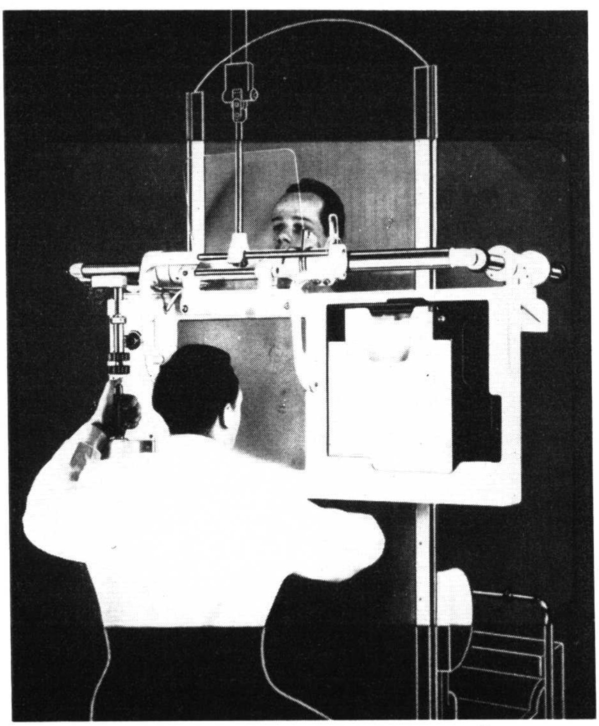

FIG. 1.—Spot-film device: Superexplorator. (*By courtesy of Siemens-Reiniger-Werke.*)

is shown in Fig. 1. Apart from the versatile form, the most important feature of these devices towards facilitating gastro-intestinal examination is that all movements are mechanically operated by compressed air, servo-motors, or other systems, and released by means of push buttons. This gives the advantage that the operator is not disturbed by the manual handling of the apparatus and may devote his full attention to the examining work.

Equipment for rapidly repeated exposures

The latest development within the range of special examinations has led to an intensified interest in the study of the rapid processes within the entire human organism. To meet these medical requirements, the manufacturers have introduced

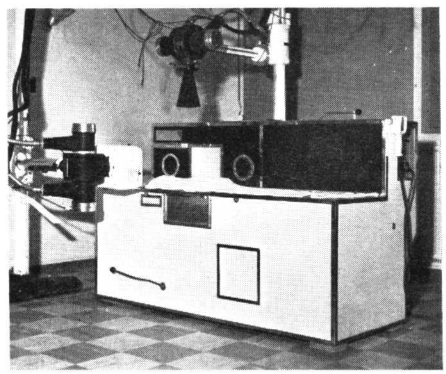

FIG. 2.—Film changer by Axén. 6 pairs of films 30 × 30 cm. a second.

a series of different apparatus for serial radiography. Two basic principles are used for apparatus of this type.

(1) The indirect method operating with miniature film and originating from the experiments of Jancker. Different types of optical cameras are used in apparatus of this design; these record a fluoroscopic image and are mostly designed for exposures in only one plane. The advantage of these systems is the production of a quick sequence of pictures, which can easily be extended to a speed suitable for ciné-radiography. Difficulties in obtaining sufficient x-ray energy during the short exposure times, the relatively large radiation dose and the loss in definition of details due to the small size of the film are, however, limitations which render this method impossible for many kinds of important examinations, as for instance angiocardiography.

(2) The direct method, on the contrary, has the great advantage of full-size pictures of usual radiographic quality and has been developed in two ways. In one of these film rolls are used, whereas in the other only normal films, either placed in cassettes or in light metal frames, are used. Machines using standard cassettes or roll films are limited to a picture sequence of about two pairs of cassettes per second often taken at right angles to each other, whereas the type using films placed in frames may be run at a speed of up to approximately 6 pairs a second.

Fig. 2 shows one of the latest models of the latter type for angiocardiography and similar examinations, designed by Axén. The two loading magazines take up about 40 films 30 × 30 centimetres, and the film-transporting mechanism is driven by an electric motor which, by means of heavy flywheels and feeding rods, pushes the film frames simultaneously into the two exposure fields where they are pressed between the intensifying screens during the exposure time. The film transport is kept at a constant level as the moving parts of the mechanism are started before the films are released for the exposures.

An aid for diagnosis by means of serial radiographs is a simultaneous record of an electrocardiogram. For that reason special contact segments are necessary to give exposure pulses to the electrocardiograph in order to trace the exposures in the ECG-curve.

An apparatus, specially designed for scientific examination of children, with cardboard cassettes 18 × 24 centimetres and having a maximum exposure velocity of 12 pairs of pictures a second, will be more thoroughly described by Wegelius and Lind in Chapter 7.

BODY-SECTION RADIOGRAPHY

The tomographic technique originating from Bocage has also developed to be of a very considerable value for examinations where an ordinary radiograph fails to reveal the presence or extent of lesions obscured by supervening structures. Chest examinations are the most frequent applications of this technique which, however, is also applied to other regions of the body, particularly to the skull and throat. The invention by Grossmann of the Tomograph enabled the achievement of longitudinal body-section radiography of patients in the prone position and the technique was shortly afterwards completed by the Planigraph which made it possible to take similar pictures of patients in upright postures. The evolution of the body-section radiography technique has furthered a demand for an apparatus by means of which layer-radiographs may be taken of patients in any position whatever. The Universal-Planigraph (Fig. 3) is a solution of this problem and was shown at the London exhibition in 1950 in connexion with the VI International Congress of Radiology. This apparatus is intended for a rigid wall mounting and the basic principle of its construction is the ordinary coupled movement of tube and film, but the supporting table and the leading rail for the tube movement are combined into a compact unit which may be adjusted to any angle and position of the patient.

As longitudinal body-section radiography is not always sufficient for the diagnosis, it has been found desirable to be able to obtain pictures of oblique or transversal layers of patients. Such a technique is enabled by the invention of the Stratigraph shown in Fig. 4. The basic principle of this apparatus is developed by Vallebona. Patient and film are in this case synchronously rotated while the tube is placed in a fixed position in such a way that the central x-ray beam strikes the patient at the point where the layer radiograph is wanted. The adjustment is made exact by means of an optical device, and indicating marks in connexion with the special patient's chair show the level of the cut. The apparatus is further fully universal, as radiographs may be made of any layer from longitudinal to transversal location by alteration of the rotating angle and the position of the film.

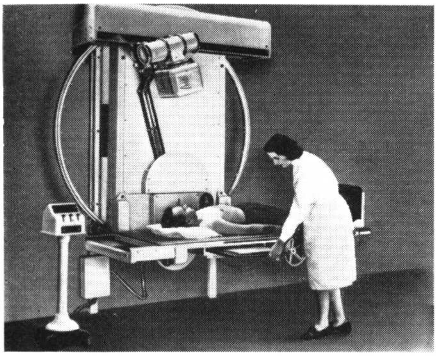

FIG. 3.—Universal-Planigraph. (*By courtesy of Siemens-Reiniger-Werke.*)

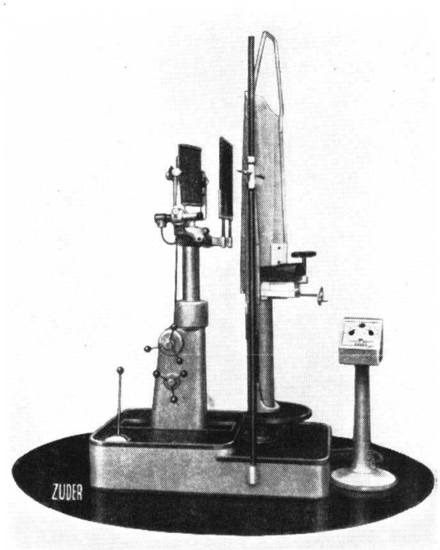

FIG. 4.—Stratigraph. Apparatus for body-section radiography with synchronously rotated patient and film. (*By courtesy of "Zuder", Genua.*)

Mass radiography units

Photo-fluorographic mass examination equipment has likewise greatly developed, gaining a steadily growing importance throughout the world as the most reliable means of uncovering tuberculosis. The invention of the Schmidt mirror camera some ten years ago as a substitute for the formerly used ordinary lens systems, involved the use of minor x-ray generators, as this camera has a luminosity of about 8 times that of the best lens systems. Accordingly, the complete examination equipment becomes cheaper to produce and maintain, more reliable, less heavy and more practical for transport purposes. The latest development in this kind of equipment has mainly been devoted to radiation safeguard problems. This is necessitated as it is found that the technical staff was exposed to considerably larger doses of scattered radiation than was formerly expected. Fig. 5 shows one of the latest portable types of mass chest survey equipment. In this apparatus the patient is completely enclosed in a protecting lead cabinet during the exposure. Patients are exchanged by drawing the rear mobile part of the cabinet backwards on its rails and this movement changes the film automatically at the same time and makes the apparatus ready for the next exposure. Blocking systems are built-in to prevent double-exposures or other irregularities and the name or number of the patient's identification card is photographically recorded on the film. A hydraulically-operated patient elevator serves the purpose of adjusting the patient to the screen, and a photo-timer secures equal blackening of the films of all patients.

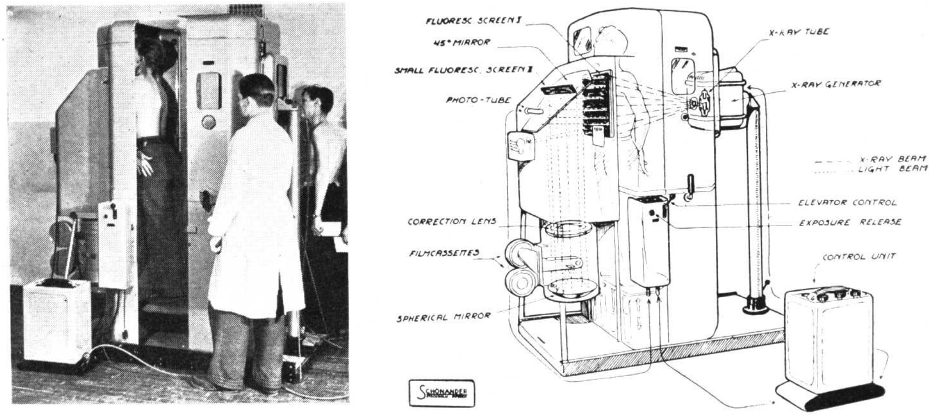

FIG. 5.—Mass chest radiography unit with mirror camera and one tank x-ray generator; Schonander FFS-4.

Film viewing cabinets

Owing to the ever increasing number of x-ray examinations made in the radiological department of hospitals, it has often proved difficult to obtain sufficiently large translumination space for the examination and demonstration of the films. In order to overcome these difficulties, different transluminating magazine systems have been developed. Fig. 6 shows a contrivance consisting of a transluminating cabinet with a desk and two film frame magazines, each of which contains 10 film frames, thus offering 20 times as large a viewing area as the cabinet itself can present. The film frames may be arbitrarily chosen for examination and the device is therefore especially useful for teaching and demonstration purposes.

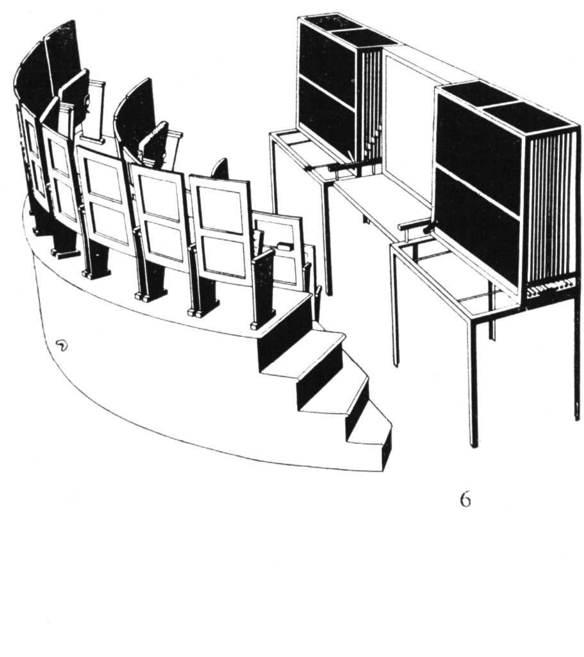

FIG. 6.—Film-viewing theatre.

TUBES AND GENERATORS

Tubes

The tube is the deciding part of radiological equipment and the other electrical parts are therefore mostly designed in accordance to a specific tube. Even with regard to the difficulties of construction and production, x-ray tubes are the most delicate items. The greatest progress recently has been made with the rotating anode types. Whereas these tubes were originally considered an instrument which could be afforded only for more specialized applications, rotating anode tubes have now become a standard part in all powerful x-ray apparatus.

The interest in higher diagnostic kilovoltages and developments of radiological methods with extremely heavy duty applications enforced the design of more powerful x-ray tubes. By increasing the size of the insert tube, the rotating discs—made of solid tungsten—from about 3 to 4 inches, and the housing, the problem was solved and a new type of tube providing a heat dissipation rate 85 per cent in excess of previous tubes was the result. Still better vacuum and other improvements of the internal insulation of the tube also rendered possible an increase from 100 to 125–130 kVp of the maximum permissible voltage, without noticeable augmentation of the inherent filtration. An excellent example of these types of tube is the Machlett Super Dynamax.

Most rotating anode tubes are fitted with two foci and the projected focal areas have been standardized to 1 $mm.^2$ and 4 $mm.^2$. In the analysis of the factors involved in definition of the radiographs it is shown that the geometrical unsharpness determined by the focal-spot size and the ratio object-film to focus-film distances often becomes the dominant factor in practice. Interesting results, however, were obtained with magnified x-ray images made by the use of a comparatively large ratio. In order to utilize this magnification, Philips, Eindhoven, brought out a double focus rotating anode tube with one focus as small as $0{\cdot}3 \times 0{\cdot}3$ $mm.^2$, the other focus being of ordinary size.

There has been produced besides the highest energy ratings of any diagnostic x-ray tube, the extreme contrary, that is, a tube with the lowest ratings since the early days of x-radiation. These are the two most interesting new designs.

In Fig. 7 a comparison of different power ratings for some of the most commonly used rotating anode tubes is given. The product mA $\times$ kVp is plotted as a function of the exposure time. There is a theoretical basis for the calculation of the rating charts but several factors of the expression must be experimentally determined. Various conceptions of the maximum allowable temperature of the target, corresponding to maximum ratings, explain the differences in curves of practically identical tubes of different make.

The stable, reliable operation of all present-day rotating anode tubes equipped in small, light-weight, shockproof housings really is an obvious proof of the high standard in x-ray engineering.

Except for some experimental purposes, all diagnostic x-ray tubes are diodes in electronic view. In 1951 at a German x-ray exhibition, however, Siemens showed an x-ray diagnostic apparatus for 150 kVp fitted with a tube of triode type. The current in this tube is controlled by the cathode-grid potential as in an ordinary

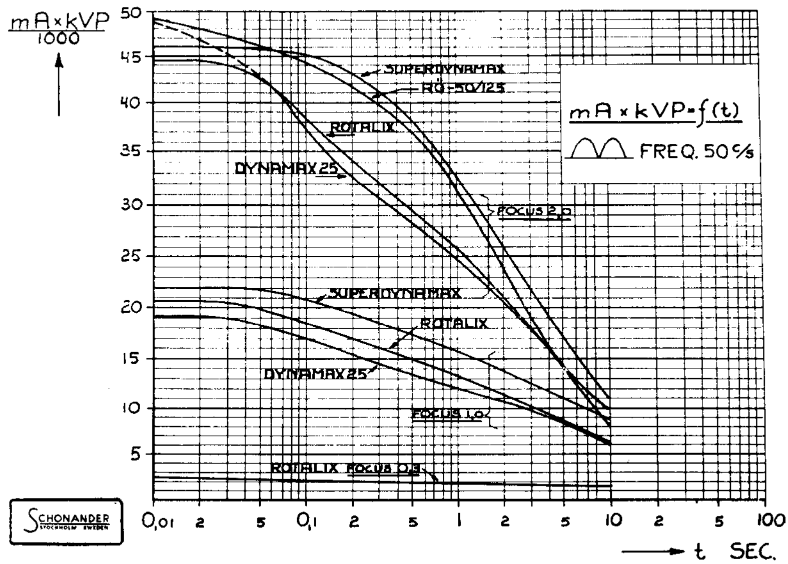

Fig. 7.—Power ratings of different foci.

electronic valve, and the exposure time is independent of the time the high tension is applied to the tube. Instead of a low voltage current precision-contactor connecting the transformer's primary leads to the line supply during the exposure, the duration of a positive voltage connected between cathode and the third electrode of this tube determines the exposure time. The action of the exposure-contactor is thus moved into the high tension circuit.

If the reliability of such a tube can be the same as that of the diode types, it presents an advantage above all for three-phase and constant potential apparatus in which the precise timing of the shortest exposures incorporates elaborate and expensive timers in order to eliminate the possibility of dangerous transient super-voltages to occur over the tube and generator, by energizing and interrupting the generator.

X-ray generators

Two adjectives, seen in all manufacturers' advertisements today, "small" and "automatic", are adequate to the trends of x-ray generator design.

Due to improvements in insulation technique, most high tension details also have become considerably smaller. High tension cables, insulated with plastic materials, are available in almost half the diameter of former rubber cables.

Air at atmospheric pressure as insulation is completely replaced with materials having higher dielectric strength and transformer oil instead of air is quite generally used in standard x-ray apparatus. In half-wave x-ray units, tube and transformer are put together in a single shockproof container filled with transformer oil. The weight of the oil in such x-ray heads, however, sometimes is a drawback, and in super-voltage apparatus where a large volume of insulation is required, the oil for that reason has been exchanged for suitable gases at high pressures.

Based upon experiences in gas insulation used in million volt generators, General Electric has introduced the gas sulphur hexafluoride (SF6) as insulation material even in a 100 kVp, 4-valve diagnostic apparatus (Gross, 1951). SF6 is in this case used at atmospheric pressure and is a colourless, odourless, non-flammable and non-toxic gas. Its density is 5·1 times that of air, so that it may be poured into an open container and will then almost completely displace air, as if it were a liquid. The spark-over voltage in pure SF6 is 2·5—3 times that of pure air, and little air in SF6 makes only a slight difference.

The major disadvantage of gas insulation is the low heat capacity of gases in comparison with transformer oil.

The filaments of the kenotrons often are the most heat producing parts of the generator. C. H. F. Müller AG, however, has succeeded in expanding the use of rectifier valves with thoriated tungsten filaments to the x-ray field. Valves with thorium cathodes are commonly used for lower voltages but previously had not been considered reliable for voltages over 20 kV. The great advance of thorium cathodes is the high specific electron emission, compared to that of pure tungsten filaments. This means a considerable gain in mA emission-current pro watt filament heating energy.

A combination of such low wattage x-ray valves, a special design of the transformers, providing these to operate at higher temperature, and gas insulation may further diminish even more powerful x-ray generators in size and weight.

"Automatic" is the most misused word in x-ray terminology. Even if there now is technical ability to design a really automatic x-ray apparatus for special application and even if there are some attempts made in that direction, the improved modern diagnostic units need in fact a more skilful operator than ever, if the apparatus is to be used to its best advantage. An x-ray apparatus is, however, called automatic, as soon as the checking of the tube rating charts is not necessary before releasing the exposure switch and has less to do with the efforts made to minimize the number of knobs and buttons for operation of the apparatus.

There are two different ways in design of preventing damage of the tube caused by incorrectly selected exposure data. The first one is an overload protection device that measures the power given off from the generator to the tube and compares this energy with the actual heat dissipation ability of the tube. This method is the most reliable of all as it measures what has happened to the tube, but has the great disadvantage of not warning the operator beforehand, should the selected power be too high, resulting in wasted films caused by interrupted exposures. The second and most generally used way is the introduction in the control unit of a pre-operating protection device which prevents the exposure being made, if the chosen mA, kVp and time represent too high a loading of the tube.

In small and medium sized apparatus such an overload-blocking system is simply realized by reducing the number of variables from three to two. There is no possibility left for the operator to select mA at will, as the mA is tied to the exposure time selector. The current is decreased continuously or in steps when the time is increased. The operating dials determining the exposure are by this method changed to kilovoltage and milliampèreseconds. In most routine work this simplified system of operation turns out to be very convenient. But for certain, more specialized examinations and especially in apparatus for high kilovoltage radiography, it is necessary to permit the operator a free choice of the three variables independently.

The overload-blocking items in these machines for that reason become a kind of calculating machine—electrical or mechanical—comparing the selected exposure data with the allowed ones, and blocking the apparatus at the passage of the load-limits. An apparatus of this latter kind, using an overload-blocking system, in which mA and kV is multiplied electrically and the product compared with the permissible power at any arbitrary exposure time, is shown in Fig. 8. The selected load is also readable on an instrument in percentage of the maximal load that any connected focus can withstand.

In more exclusive apparatus, like the above mentioned, precautions are taken to ensure that the milliamperage remains at its predetermined value independent of the kilovoltage variations as well as the fact that the indicated kilovoltage always is the correct tension over the tube also for changes in line conditions. The incorporation of compensation systems for obtaining correct reproduction of the final exposure factors is sometimes also meant with the prefix "automatic" and in this definition may be of some practical use.

The large power of modern diagnostic machines has necessitated new designs in timers and contactors. In order to eliminate the inductive effects, occurring at "make" and "break" of the large primary currents, effects which can consist of transient super-voltages liable to damage the tube or cables as well as the high tension transformer, so-called synchronous or impulse timers are used.

These are mostly electronic devices ensuring that the primary circuit is closed and opened at the moments when the current is passing zero or at least has a relatively low amplitude. For three-phase x-ray apparatus the contactor problem, as previously mentioned, has an elaborate and expensive electronic solution. Such timers, however, utilizing 6 thyratrons as an exposure contactor, are manufactured. The shortest possible exposure time is by this decreased to 7 milliseconds.

A unique system of purely electronic control of the x-ray generator is developed by General Radiological Ltd. (Quittner, 1950). The output kilovoltage of a conventional 4-valve apparatus is smoothed by a pair of high tension condensers, diminishing the voltage variations to a lower value than peak to zero. By means of two triodes in the high tension circuit this pulsating voltage supply is transferred to a stabilized DC voltage over the tube. The kilovoltage selection is affected by control of the grid potential of the triodes. The DC output is thereby achieved in such a way that a fraction of the tube voltage is compared to a stabilized and adjustable reference voltage, and differences of a reduced tube voltage and the reference voltage control the input to high-frequency oscillators, the output of which also controls the grid potential of the high tension triodes. The starting and ending of the exposure is made by means of the same oscillators and control valves, which carry out the voltage control. This system of electronic control renders dispensable conventional auto-transformers and exposure contactors in the primary circuit.

In conjunction with the design of x-ray generators, the advantage of standardization of information about the generator's power rating ought to be impressed. The utilization of a powerful generator is very closely combined with the quality of the mains supply. The drop in line-voltage, ensuring a high energy exposure,

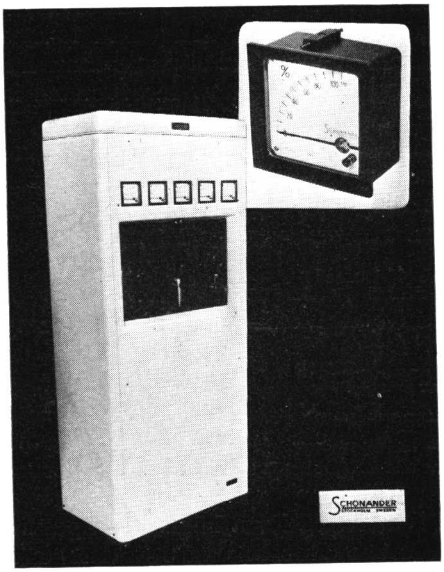

FIG. 8.—Control unit, 125 kVp, 1,000 mA 4-valve generator; Schonander DIK-1000.

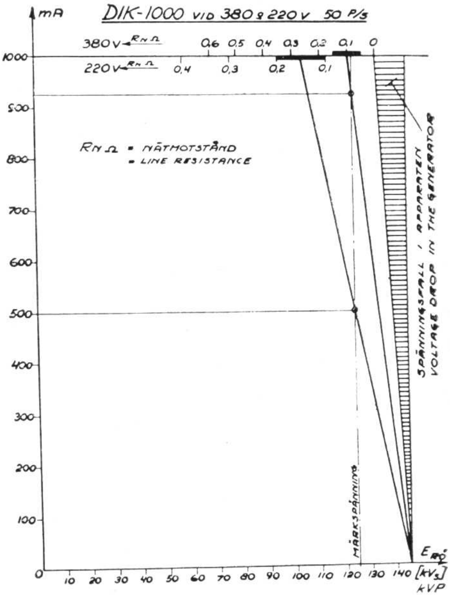

FIG. 9.—Rating chart of output power for the x-ray generator DIK-1000. mA is 500 at 125 kVp, line voltage 220 V and line resistance 0·15 ohm. 925 mA at line voltage 380 V, 0·10 ohm.

is in all mains considerable. For that reason, the output of an x-ray generator highly depends upon the quality of the mains, and this quality may be most easily determined by the measurement of the internal resistance of the line. Preliminary standards of the record concerning efficiency of x-ray generators and of the general roentgen-terminology have newly been accepted in Sweden. All output figures have to be stated according to a line resistance of 0·1 ohm, being an average value of the 220 volt supply in large hospitals. A more detailed diagram, giving all information about the generator at various line conditions, is shown in Fig. 9.

An investigation of the actual supply and a study of such a diagram representing a maximum power chart of an x-ray generator would be a good rule before choosing the most suitable one, and thus precluding later disappointments.

PHOTO-TIMERS

The usefulness of an objective method for determination of the radiographic exposure is obvious. More than 20 years ago, Franke (1930) devised a suitable method by using photocells and amplifiers for measurement of the intensity of an x-ray beam after passage of the object, and timing the exposure in accordance with the measured value. The technical means for a reliable timing mechanism