ELECTRONICS AND TELEVISION & SHORT-WAVE WORLD

SEPTEMBER, 1940

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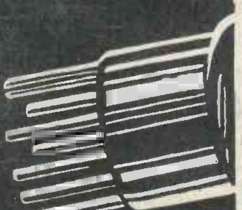

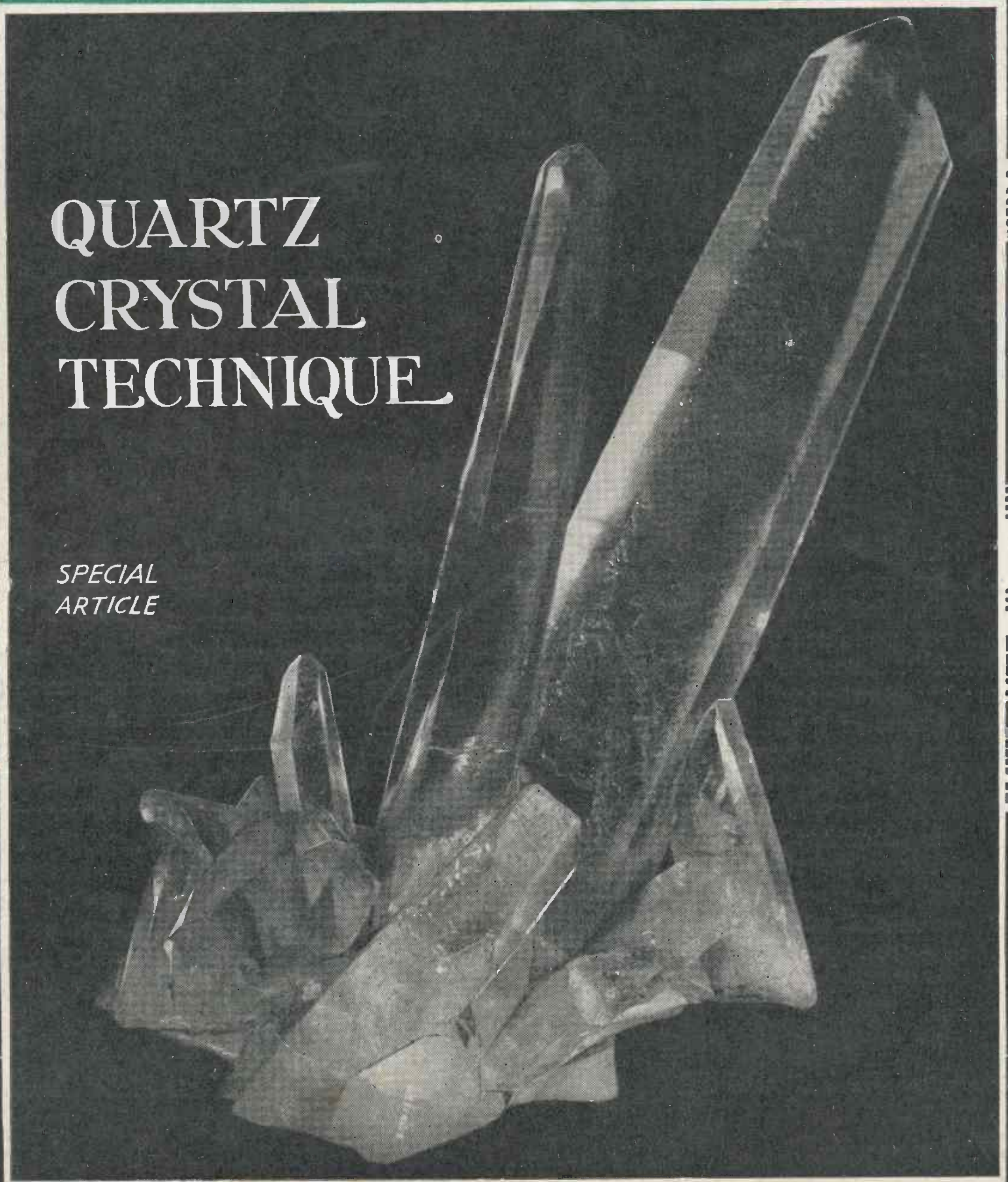

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PRINCIPAL CONTENTS

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Page

Stereophony in the Kinema 388

Modern X-ray Apparatus and its Applications 389

An up-to-date résumé of modern X-ray apparatus and its practice.

Gas-filled Triodes and their Practical Use ... 395

New Electron Microscope 398

Details of a microscope giving 25,000 diameters magnification.

A Linear Sawtooth-current Generator ... 399

Avoiding Defocusing with Electrostatic C.R. Tubes 400

News Brevities 401

Development and Application of Quartz Crystal Technique 403

Correcting Frequency Drift in Radio and Television Receivers 407

Recent Developments 408

High-voltage Power Supplies 410

A Frequency-modulated Beat-frequency Oscillator for Visual Ganging of Radio Sets 413

A review of an oscillator intended for use with the Cossor oscillograph.

Improved Armature Pick-up 415

Short-wave Radio World 416

Power Output 418

74-range Universal Meter 422

Lighting by Fluorescent Powders 427

Novel Holder for Miniature Valves 430

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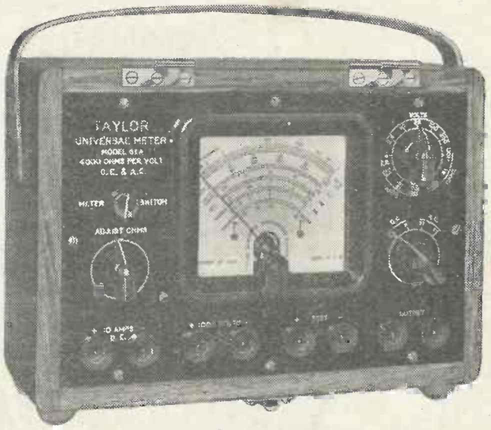

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News and Views

BECAUSE of the war, the matter of frequency modulation has not received a great deal of attention in this country and the general attitude towards it has been that it is an interesting development which could wait until more normal times. Reliable reports from America, however, state that the Germans have not been slow to recognise its advantages in the field and that it is finding considerable use with the German mechanised forces. The particular advantage of frequency modulation for a service of this kind is, of course, that it is relatively free from the effects of electrical disturbances caused by ignition systems of mechanical vehicles. America also, it is stated, is employing frequency modulation control for mechanised units.

Tests of a general nature have recently been carried out with this system by the General Electric Co. (U.S.A.) and it has been found that the area of good broadcast reception with frequency modulated radio is 33 times greater than with amplitude, or present type, broadcasting.

These calculations were made by using two amplitude and two frequency modulated transmitters operating on the same wavelength and placed on level ground 15 miles apart. First the two amplitude transmitters each operating on 1 kilowatt were calculated to operate simultaneously. The area served without interference about either transmitter was limited to a radius of $1\frac{1}{2}$ miles. Next the two frequency transmitters on the same 1 kilowatt of power were calculated. The area covered without interference was 33 times greater.

In the second condition the power was increased to 10 kilowatts on one transmitter and remained at 1 kilowatt on the other. With amplitude, the clear reception area of the 1-kilowatt station was reduced by interference from the stronger station to one-third its size, and the area of the 10-kilowatt station increased to about 3 times. When a change was made to frequency modulation, under the same conditions, the clear area for the 1-kilowatt station was reduced one-fourth, whereas with the 10-kilowatt station the area was increased about three times.

The third calculation was made with the power of the transmitter at one point increased to 100 kilowatts with the other transmitter remaining at 1 kilowatt. With amplitude modulation, the clear area of the 1-kilowatt station was reduced to one-eighth area, and the 100-kilowatt station area was increased approximately three times. With frequency modulation, the area of the 1-kilowatt station was reduced to about one-tenth its size and the area of the 100-kilowatt station increased about $4\frac{1}{2}$ times. The same frequency can be assigned to a large number of stations which do not have to be separated by very great distances, and at the same time the stations can cover a greater area with good reception than is possible by amplitude modulation.

As stated, these tests were of a general nature, but it is evident that the same advantages will accrue when the system is used for the many exacting requirements of war conditions.

An interesting article in the current issue of the "R.C.A. Review" describes some experiments with a steel tape recorder on the effects produced by reversing normal speech sounds and words. It appears that reversal of certain vowel sounds shows that they are in effect a sequence of two sounds, although represented by a single letter.

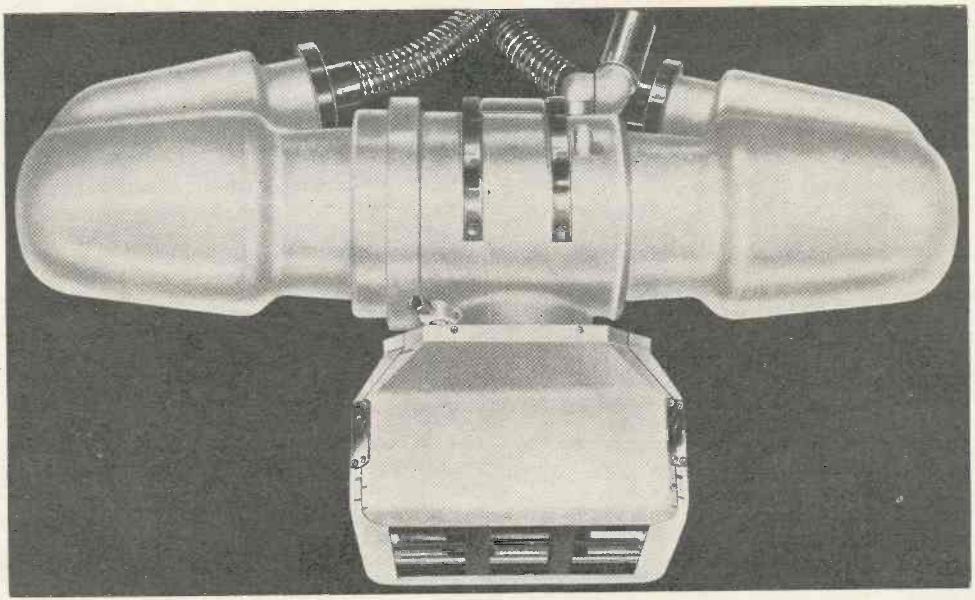
For example, "i" in reversed sound is "e-a" and "w" has the sound of "oo" although usually considered as a consonant. The experiments recall a similar demonstration given some years ago with the Marconi-Stille apparatus at the Physical Society's Exhibition, when members amused themselves by counting with reversed sounds of the numbers. The most satisfactory sound to give the word "one" was made by reversing the word "nouf" and the analysis of the reason for the alteration formed one of the points in the discussion. Readers who have constructed Dr. Mansi's steel wire recorder which was described recently in this Journal may like to try some experiments for themselves.

THERAPEUTIC ELECTRONICS

Modern X-Ray Apparatus and Its Applications

By RONALD L. MANSI, M.R.C.S., L.R.C.P., D.M.R.E.(Camb.).

A knowledge of the properties of X-rays and radium provides a useful basis for the understanding of other branches of electronic engineering, the more so since their discovery stimulated the brilliant researches which resulted in the elucidation of the nature of the atom and electron. There are still a number of matters in connection with X-rays on which, at the moment, there is not complete agreement, but this article deals with generally accepted theories and the more recent practical applications.



Rotating-anode X-ray tube complete in its shock and ray-proof casing. Cooling is by forced air circulation.

(Courtesy Siemens)

X-RAYS were discovered by Professor Roentgen in 1895 and it is a curious fact that although Sir William Crookes, Professor Lenard and others, performed such a large amount of work on cathode rays prior to Roentgen's discovery and must have produced X-rays in considerable quantities, they failed to recognise them as such. It remained for Roentgen not only to discover them but to investigate fully most of their physical properties.

Following Roentgen's discovery it became apparent that *whenever cathode rays at high speed are made to strike a body of relatively high atomic weight then X-rays are produced.* This fundamental axiom became the basis upon which all subsequent forms of X-ray tubes were developed.

A television cathode-ray tube or even an ordinary wireless valve is a potential X-ray tube if the anode voltages could be increased and means provided for focusing the cathode stream on to a suitable metallic target within the tube. Of course, these would not provide efficient sources of X-rays, but they illustrate the principle. Furthermore, the development of the modern television tube followed a close parallel to that of the X-ray tube in the following manner.

It will be remembered that the original Braun cathode-ray tube depended upon the residual gas in the glass bulb to produce the cathode discharge by ionisation of the gas and there was no hot filament to provide the source of electrons as in present day tubes. Similarly, all the early X-ray tubes were what is known as "gas" tubes.

The cathode was bombarded by positive ions set free from the residual gas by the electric discharge. This bombardment set free electrons from the cathode which were focused on to the anti-cathode or target and produced the X-rays. Thus the amount and quality of the X-rays produced were dependent on the amount of gas or degree of vacuum in the tube, and the accurate regulation of this amount of gas to produce consistent results from the tube constituted one of the greatest disadvantages of the gas tube. Several ingenious types of air valves and such like devices were produced to facilitate this adjustment of vacuum, some of which worked with considerable success.

This type of X-ray tube is not used in modern installations, having been displaced by the hot-cathode type of tube introduced by Coolidge just before the last war. This type of tube derived

Hot Cathode Advantages

its cathode stream from a hot filament similar to a modern television tube and this innovation did away with numerous disadvantages of the gas tube. Its superiority is based, briefly, on the following points :—

1. Since the cathode stream did not depend upon the number of gas molecules remaining in the tube, the tube could be exhausted to the highest possible degree of vacuum and permanently sealed. This eliminated one point needing constant attention.

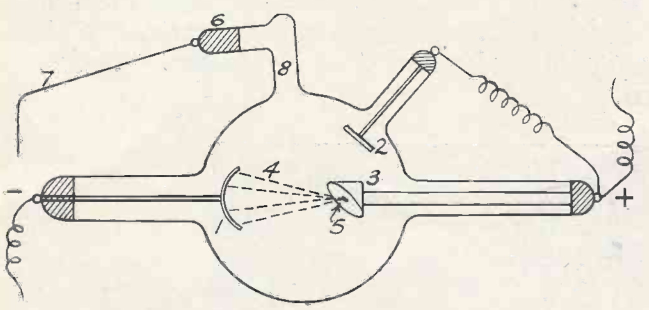


Fig. 1. Diagram of Gas X-ray tube.
1, Curved cathode for focusing cathode stream 4, on to the target 5, usually a tungsten button set in a solid mass of copper forming the anti-cathode 3. The true anode 2, is not placed in the path of the cathode stream, but is connected to the anti-cathode as shown. This prevents sputtering and ensures steady working. 8, device for automatic regulation of vacuum. 6 is a plug of absorbent material retaining a small amount of gas. 7 is a wire placed a small distance from cathode cap. When vacuum gets too hard sparks take alternative path to 7, warm the plug 6 and release small quantity of gas, thus lowering the vacuum and sparking ceases as easier path is now provided through the tube.

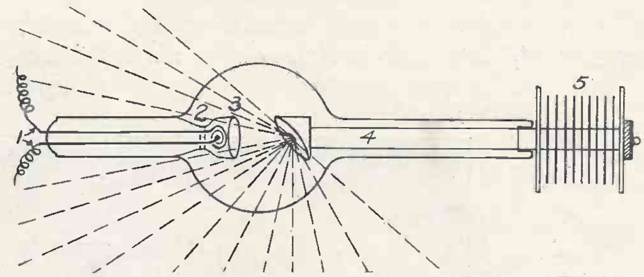


Fig. 2. Coolidge-type tube, radiator air cooled.
1 shows the leads running to the filament spiral 2 within the cathode 3. Target is set in a solid copper rod running to the outside of the tube with air-cooled fins 5. The actual X-rays spread out from the target in all directions as shown by the dotted lines.

2. Because of the high vacuum much higher potential differences could be applied to the tube thus enabling X-rays of greater penetration to be obtained.

3. Control of output was much simplified as by varying the brightness of the filament the amount or quantity of X-rays could be varied at will and by adjusting the kilovoltage across the tube the degree or " quality " of penetration could be so well controlled that it became possible to compile accurate tables giving the factors in milliamperes, kilovoltage and seconds which it was known would produce consistent results in taking radiographs of the different parts of the human body or other subjects.

4. Fixity of the focal spot. In the gas tube owing to the dependence of the discharge upon the residual gas the focal spot on the target had a tendency to wander, often imperceptibly, but sufficient to impair the sharpness of the resultant X-ray photograph. In the Coolidge-type tube this defect is absent.

5. Self-rectifying action. As an X-ray tube is essentially a very high voltage operated instrument the supply of current is usaully from an A.C. transformer. It is, however, necessary to supply D.C. current to the tube, and the Coolidge-type tube, just as in a wireless valve, by virtue of the design of its electrodes has the property of rectifying its own current provided the anode does not become red hot, when, of course, it will emit electrons itself and cease to rectify.

This useful property is utilised in small X-ray installations where special provision is made for keeping the tube cool when running, but no provision is made for supplying rectified current. When, however, a tube is supplied with rectified current it will continue to emit X-rays efficiently even when the anode is red hot.

6. This type of tube is capable of handling much larger currents and voltages than the gas tube and thus reduces enormously the time necessary for radiographic exposures, etc.

Figs. 1 and 2 show diagrammatically the essential features of construction in one type of gas tube and the Coolidge-type tube respectively.

The gas tube should not be deprecated unduly since all the fundamental work on X-rays, both in medicine and physics, was accomplished by its use, and when handled correctly and time is not an important factor it is capable of producing some very good radiographs.

Besides their low cost, gas tubes have the virtue of simplicity in construction: they need no separate filament current source and although not now used professionally they are quite useful for experimental work.

The Nature of X-rays

Although cathode rays are essential to the production of X-rays there are many differences in their respective properties. Cathode rays are strongly influenced by magnetic or electrostatic fields, a property made use of in the design of modern television tubes. X-rays, however, are not influenced by such fields.

It was shown by Professor J. J. Thomson in 1897 by a series of brilliant experiments, using a tube not unlike a television tube, that cathode rays consisted of definite particles of matter with a mass infinitely smaller than any known atom, about 1/1,800th of that of a hydrogen atom, and that they carried a negative charge; in short they are what are now known as electrons and are actual particles and not really rays.

X-rays, on the other hand, have no mass, but the generally accepted view is that they are electro-magnetic waves of exactly the same nature as wireless waves, visible light, etc., but very much shorter wavelength. The range of X-ray wavelengths in common use extends from about 1.0 to 0.05 of an Angstrom unit in the electro-magnetic scale. (The Angstrom unit equals one millionth of a millimetre or 10^{-10} metre.)

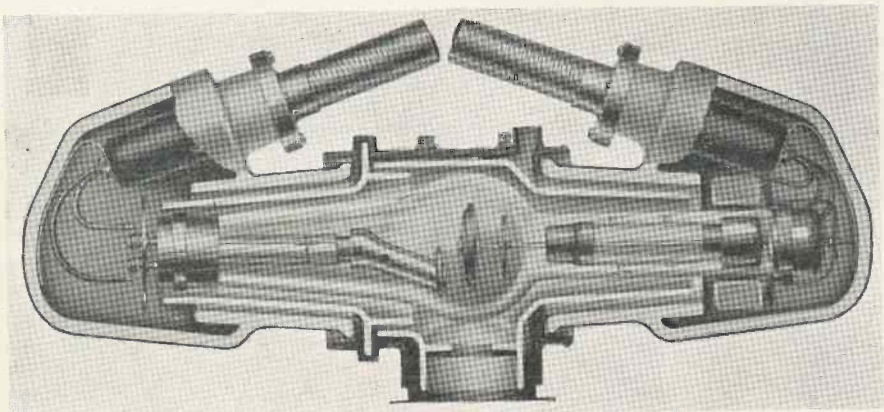
Following the usual law applicable to electro-magnetic waves it is apparent that the frequency of the X-rays of the shorter wavelengths is extremely high.

This extreme shortness of the wavelength of X-rays was demonstrated by Laue, Bragg and others.. It had already been considered that the wavelength was short because of the failure of polished surfaces, etc., to reflect X-rays and Laue suggested that the regular atomic arrangement of the structure of crystals might act as an ideal diffraction grating for the rays if they were as short as was suspected. This ingenious suggestion not only proved to be correct, but it was found possible from the results to calculate the actual wavelengths of the rays being examined and to confirm their extreme shortness.

The wavelength of the rays emitted from the tube depends upon the nature

X-ray Characteristics

of the metal of the target, and the velocity of the cathode stream, which in turn depends upon the kilovoltage applied to the tube. It may be said that the velocity of the cathode stream depends on the square root of the voltage, but the relationship between the kilovoltage and the wavelength of the X-rays produced is complicated by the fact that the X-ray beam is usually heterogeneous, consisting of rays of different wavelengths.



This sectional picture shows the assembly of the rotating anode tube inside its casing. Note the stator winding for driving the anode surrounding the tube.
(Courtesy Siemens)

This is due in the main to three factors :—

1. The slight variations which are always present in the high tension supply, due to mains fluctuations, and which are naturally magnified by the high step-up ratio of the transformer. This has been eliminated to a large extent in modern "constant voltage" installations which will be discussed later.

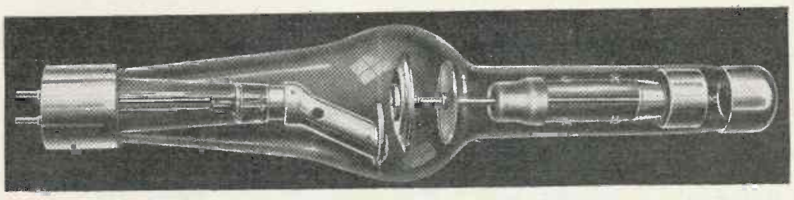
2. The surface of the target or anti-cathode, compared to the size of an electron, is exceedingly irregular, although it may appear highly polished to the eye. Although some electrons may strike the metal head on and give up their energy to produce X-rays of one definite wavelength, others will strike a depression or an elevation in the surface of the metal and glance off at an angle to another part of the surface. Thus their speed is reduced in stages and the wavelength of the resultant X-rays will correspond to the speed of the electrons at the moment of the various impacts.

3. The influence exerted by the nature of the metal comprising the target is as follows: Although the axiom stated at the beginning of this article holds true, at and above a certain kilovoltage the metal comprising the target, according to its atomic weight, also gives out "characteristic" X-rays of a definite wavelength which mix with the others in the beam. It may be stated that in general the higher the atomic weight of the metal the shorter is the wavelength of the "characteristic" waves produced. Thus in practice an X-ray beam of one definite wavelength is not obtained, but by suitable filtration through copper or aluminium filters most of the unwanted longer wavelengths can be filtered out.

It may be said that the higher the kilovoltage the shorter is the wavelength of the X-rays produced and the more penetrating they become. We can, however, calculate what will be the shortest wavelength produced in the heterogeneous beam by applying the expression :—

$$\text{minimum wavelength in Angstrom units} = \frac{12{,}400}{\text{maximum voltage}}$$

As is well known cathode rays can be focused to a point and for this reason the earlier tubes had cup-shaped cathodes so that the rays could be focused on to the anti-cathode which was placed at the focal point. This is necessary because the smaller the point source of the X-rays the sharper will be the definition of the resultant radiograph or fluorescent screen image.



Rotating-anode tube without its casing.
(Courtesy Siemens)

X-rays cannot be focused, reflected or refracted by any known agency, and as soon as they originate at the target they spread out in every direction, as shown in Fig. 2. It is, therefore, necessary to provide heavy metallic adjustable diaphragms and shields on the tube so that only those rays needed in a certain direction are used.

Those rays which are cut off are literally wasted and they must be prevented from spreading out far from the tube as they are very dangerous if the human body is exposed to them for any but short periods.

This wasting of rays is unavoidable since they cannot be focused, and in fact from the electrical point of view an X-ray tube is a very inefficient instrument, only a very small percentage of the electrical input being converted into X-rays and most of these rays are lost in the manner described above. However, no better method of obtaining a higher efficiency has been discovered.

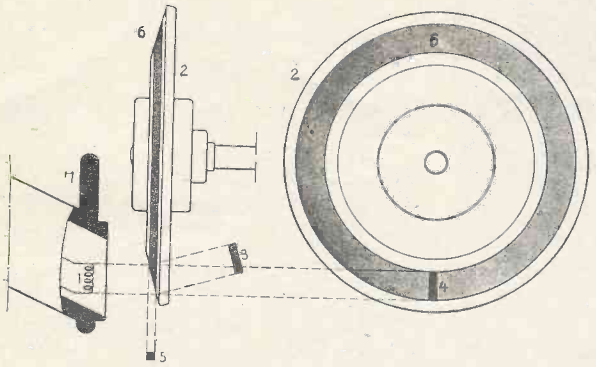
The greatest loss occurs in the heating of the target. Because of the focusing of the cathode rays on to one point a great deal of heat is evolved and if the rating of the tube is exceeded this would soon melt the target so that special provisions for cooling the anode have to be made which will be described in due course. On the other hand, the X-rays themselves produce only a negligible heating effect in bodies which they encounter.

The power of penetration of cathode rays in air is very limited and easily stopped by thin plates of metal. X-rays, however, have great power of penetration through solid matter and, of course, this has formed one of the chief fields of their practical application. Different substances offer a different resistance to their passage and the higher the atomic weight of a substance the more resistance it offers to the passage of the rays. It is because of this variation that it is possible to interpret the resultant screen image or radiograph. This image is seen as a series of shadows of different densities or opacities superimposed upon each other and since they are essentially only shadows they are subject to the same law as those cast by visible light since X-rays also travel in straight lines.

Thus, if the object to be X-rayed is not placed as closely as possible to the screen or film considerable distortion of the image will result. In cases in which it is desired to gauge accurately the size of an object invisible to the eye, the tube is placed a considerable distance from the object. Thus, in radiography of the chest where it is desired to ascertain the size of the heart the tube is often placed some six feet from the patient.

Unfortunately, since the amount of X-ray radiation relative to distance, follows the same inverse square law as that of visible light, it is necessary to square the output of the tube for every unit of distance the tube is moved away. Since the " quality " or kilovoltage will remain the same it is necessary to increase the " quantity " of rays or milliamperage or exposure time in seconds or both according to the capacity or rating of the tube. This imposes a limit to the distance to which the tube may be moved, but from calculations the magnification error at six feet or other distances can be allowed for.

The factors kilovoltage, milliamperage and time in seconds are of importance. When an X-ray tube is working at " saturation point," that is, when all the electrons from the filament are being utilised, unlike an ordinary valve, any increase in the anode voltage will not increase the milliamperage through the tube. The electrons, however, will be speeded up and will consequently produce X-rays of shorter wavelength, but any increase in the filament temperature will release more electrons and thus increase the quantity of electrons or the milliamperage through the tube, although their speed will remain the same if the kilovoltage is not altered. We thus have two convenient and independent methods of control of the tube. For penetrating objects of different densities the kilovoltage is adjusted and the time of exposure is governed by adjusting the filament temperature within the limits of the tube and the number of seconds of exposure. The expression " milliampere-seconds" is used in reciprocal to denote the exposure time according to the rating of the tube. Thus, a powerful tube passing many milliamperes will need a shorter exposure than a smaller tube passing only a few milliamperes for radiographing the same object.



Figs. 3a and 3b. Illustrating the principle of the rotating-anode and line focusing.

The cathode remains stationary. The rotating anode 2 is seen in profile. Note the bevelled edge on which the cathode stream impinges. 1 is the longitudinally placed filament and 3 represents its area projected on to the bevelled edge of the rotating anode. 5 represents its optically effective area as X-rays projected through the outlet window of the tube. In this way a large area of target is utilised to give a more defined source of X-rays with improvement in definition and heat dissipation in the anode. 7 is a shield for stray electrons.

Fig. 3b. Front of rotating-anode.

4 is the projected image of the filament and 6 is the annular track which traverses the cathode stream.

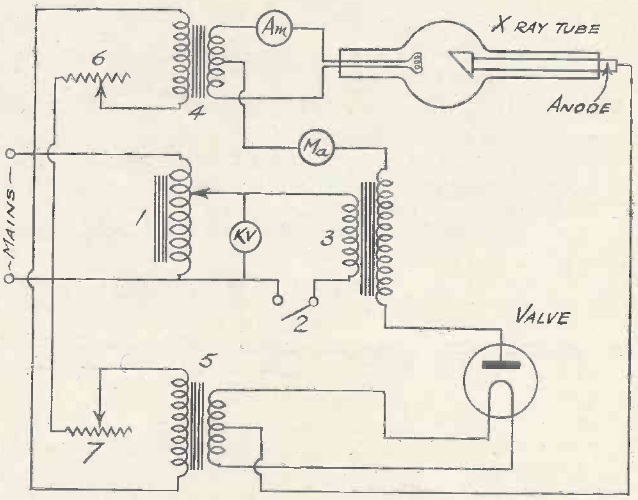


Fig. 4. Single-valve radiographic installation circuit.

1, auto-transformer with selective tappings for K.V. 2, switch across which may be connected time exposure apparatus. 3, main high-tension transformer, K.V : pre-reading kilo-voltmeter M.A : milliammeter in high-tension circuit and A.M : Ammeter in filament circuit of X-ray tube. 4, X-ray tube filament transformer. 5, valve filament transformer, 6, tube filament rheostat. 7, valve filament rheostat. Mains switches and fuses are inserted on low-tension side of generator (not shown).

Scattering Effects

When X-rays pass through matter several changes in the rays take place. Like light rays passing through a cloudy fluid, some of them are scattered in all directions, but unlike light these scattered rays undergo a change in wavelength which becomes longer than the primary X-ray beam. This has been explained by Compton as resulting from a collision of an X-ray quantum of energy with a free electron in the scattering substance. The electron " recoils," carrying with it some of the energy of the quantum with a resultant increase in the wavelength of the secondary rays produced. If the quantum encounters an electron which is not free, then the electron cannot "recoil" and no change of wavelength takes place in the quantum which has not lost any of its energy.

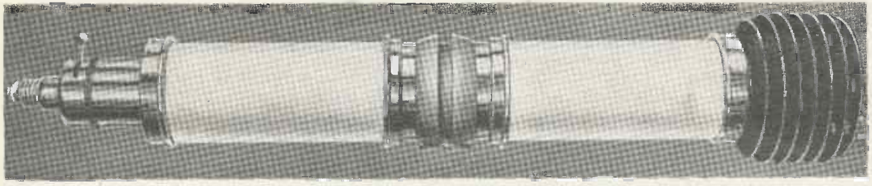
If the scattering body is a metal and the primary X-ray beam is of a shorter wavelength than the " characteristic " rays of the metal, then these " characteristic " rays will be excited in the metal and will be given out in all directions and will mix with the main beam. This factor must be allowed for in choosing suitable metal for the filters used. Furthermore, the primary X-ray beam will liberate electrons from the surface of the body which have been shown to have the same velocity as those which produced the primary X-ray beam in the tube.

These scattering effects are of great practical importance. The scattered radiation, after passing through a thick body, tends to impair the sharpness of the resultant image and special screens or grids have been developed to minimise this effect. In addition, although the primary beam may be well shielded from the operator, he may receive a dangerous amount of scattered radiation from the object he is examining. Since the scattered radiation contains a large

Modern Apparatus

amount of the "softer" or longer X-rays, this danger is increased. The human skin is very sensitive to X-rays, prolonged exposure to which will produce very serious skin lesions. Since the "softer" rays have a smaller power of penetration, the skin will absorb most of them and suffer the brunt of the radiation whereas the "harder" or more penetrating rays will pass through the skin and affect the more resistant organs within.

This action of the rays on the living cell produces profound changes within the cell and forms the basis upon which the whole science of X-ray therapy in medicine for the treatment of certain serious conditions has been built up. As X-rays are capable of producing such violent atomic disturbances and have such power of penetrating solid matter it is not surprising that they should be be capable of producing remarkable changes in the delicate structure of living cells.



Modern non-shock proof tube with air-radiator cooling. This tube is of the stationary-anode type with twin-line focus. Note ray-proof casing.

(*Courtesy Siemens*)

The power of X-rays to excite fluorescence in certain chemicals and to affect photographic emulsions is well known and forms the chief method by which their presence is rendered apparent. This aspect of X-rays will be described in more detail later in the article.

A very useful property of X-rays is their ability to produce ionisation in the air through which the rays pass. Since it has been shown that the number of ions produced is proportional to the intensity of the X-ray beam, this has served for the basis on which a number of instruments have been devised to measure the intensity of the X-ray being produced from a given source. This is a very important factor in the practice of X-ray therapy as it is essential that the dose of X-rays the patient is receiving be accurately known as there is no immediate biological reaction apparent to the operator.

This power of producing ionisation in air with even a moderately powerful beam of X-rays can be readily detected up to forty or fifty yards away by the simple gold leaf electroscope. The electroscope is first given a charge so that the leaves diverge and upon exposure to the rays the rate of fall of the leaves is observed. By comparing this rate of fall with that produced by a known standard source of radiation an estimate of the unknown source can be formed.

More modern "dosimeters" as they are called, employ a small ionisation chamber which can be placed in the path of the rays and which is flexibly connected to the measuring instrument which may be situated in another room. The ionisation current flows through a special resistance across which the voltage drop due to the loss is measured directly and is calibrated to read in International Units of dosage.

Design of Modern Apparatus

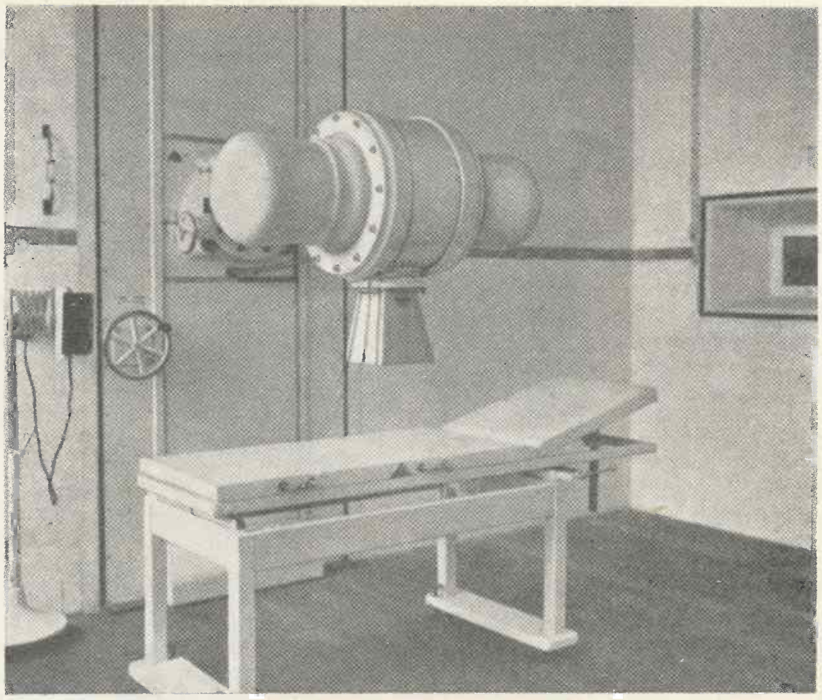
X-ray apparatus has made great strides during the last few years. In the earlier apparatus the X-ray tube itself was one of the weaker links in the chain as high tension generators of large output were already well developed; but ths state of affairs has now been largely remedied and indeed it may be said that in the case of the million-volt tubes the position has been somewhat reversed.

Some idea of the progress in tube design can be gauged from the fact that whereas a few years ago three kilowatts was considered quite a good rating for a tube, one type of modern rotating anode tube working with a six-valve (three-phase) generator is capable of an output of no less than forty kilowatts for 0.1 second.

The chief improvements are as under:

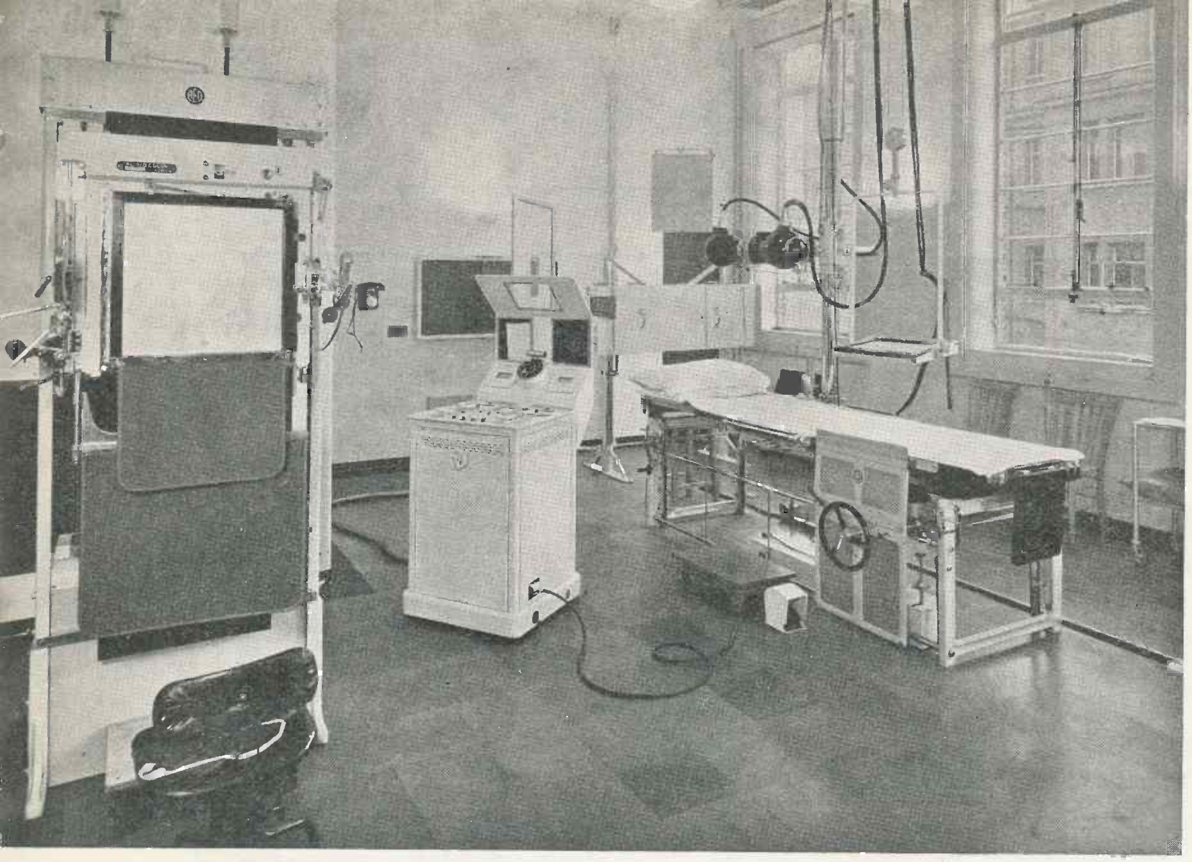
1. *Protection from shock*: Because extremely high voltages are always used in radiology and the tube has often to be manipulated in close proximity to the subject and the operator, protection from the danger of shock is very important. The following voltages are in common use. From about 10 to 15 kV for relatively transparent objects such as the X-ray examination of paintings, etc. From about 40 kV for crystal analysis (X-ray spectroscopy). From about 50 kV to 100 kV for medical diagnostic purposes, and up to 200 kV and even 400 kV for medical therapeutic and industrial purposes such as the examination of thick steel castings for flaws, etc.

During the last few years generators and tubes have been built to operate at voltages up to a million for use in medical deep X-ray therapy in an effort to produce X-rays of a wavelength approaching that of the short wavelength gamma rays of radium; research is still proceeding on these lines.



Shockproof 400-kilovolt therapy equipment with oil-immersed tube. Adjustable metallic shutter behind separating the tube from the generator room. Note the large size of the tube compared with the couch.

(*Courtesy Siemens*)



MODERN X-RAY DIAGNOSTIC OUTFIT IN A LARGE HOSPITAL

Upright screening stand on the left and all controls and adjustment for height, diaphragms, etc. The tube is behind. Note the lead rubber aprons below the screen to shield the operator from scattered radiation and at the same time to allow a certain amount of flexibility for physical examination of the patient during screening. On the right a table with under-couch and over-couch tube and drive for the tomographic attachment of the over-couch tube. Metal panels for protection of the operator surrounding the large wheel for controlling the undercouch tube at the front of the tube. This tube runs on tracks over the length of the table. Fluorescent screen suspended on pulleys from the ceiling over the couch.

(*Photo : courtesy A. E. Dean & Co.*)

In non-shockproof tubes (of which many are still in use) the electrodes are connected to the overhead gear by wires which automatically wind up or unwind as the tube is moved about. The shockproof tubes, however, have large insulated bulbous casings of high dielectric strength through which enter the shockproof cables from the generator.

2. *Cooling*: Air, water and oil cooling of the anode are all employed according to the purpose for which the tube is used. Air cooling, either radiator or centrifugal blower, is generally used for a diagnostic tube, and water or oil cooling, often circulated by pump, for continuous operation as used in deep X-ray therapy. This cooling of the anode is very necessary since most of the energy supplied to the tube is dissipated as heat in the anode which would soon melt if not specially cooled. The cooling fluid is led right up the body of the anode, which is hollow.

3. *The Design of the Electrodes*: The metals for the electrodes are chosen according to the conditions under which they have to work. The target is usually a small piece of tungsten set in a mass of copper which forms the main body of the anode. Tungsten has a very high melting point which enables it to withstand the heating effect. Its atomic weight is also high so that its "characteristic" rays are emitted at a fairly high kilovoltage, about 69,000 volts, and its vapour tension is low.

(*Continued on page 424*)

On the right a motor-driven tilting table which can be used in the horizontal or vertical position. Table for general radiographic work on the left. Against the wall on the left is seen a wall pattern dental unit. Note use of shockproof H.T. cable everywhere. H.T. generators in roof. All-change over H.T. switching remotely electrically controlled.

(*Photo : courtesy A. E. Dean & Co.*)

25,000 Dia. Magnification with
A New Electron Microscope

BRIEF mention was recently made in this journal of the development by the R.C.A. Research Laboratories of an electron microscope capable of a magnification of 25,000 diameters. Further details of this remarkable new instrument, which was designed and constructed under the supervision of Dr. Vladimir K. Zworykin, well known in electronic development, by Dr. Ladislaus Marton, a pioneer microscopist, are now available.

The electron microscope which was demonstrated at the R.C.A. Laboratories, Camden, magnifies objects by electron means twenty to fifty times as much as is possible with the finest optical microscope in existence, and the R.C.A. engineers expect an even greater useful magnification will be attainable in the future.

The resolving power or sharpness of definition of the new instrument is so high that useful magnification may be increased up to 100,000 diameters by photographic enlargement. Ordinarily useful magnification of objects under optical microscopes cannot be achieved above 1,500 diameters in ordinary light, or above 2,500 in ultra-violet light, because resolution, or sharpness of definition, is lost beyond those points.

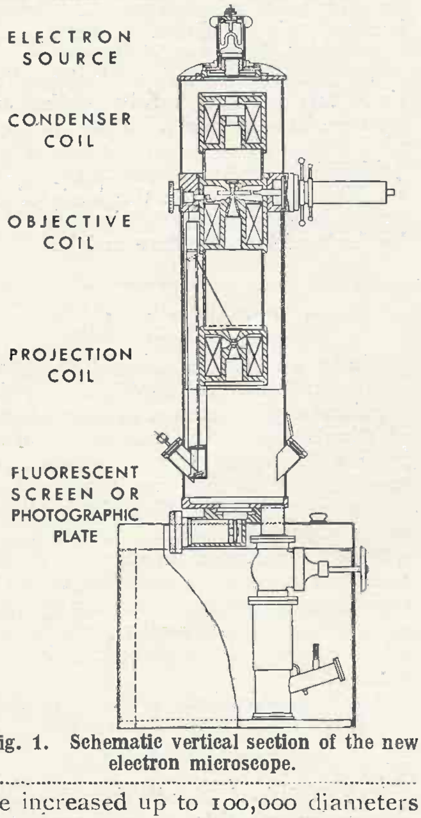


Fig. 1. Schematic vertical section of the new electron microscope.

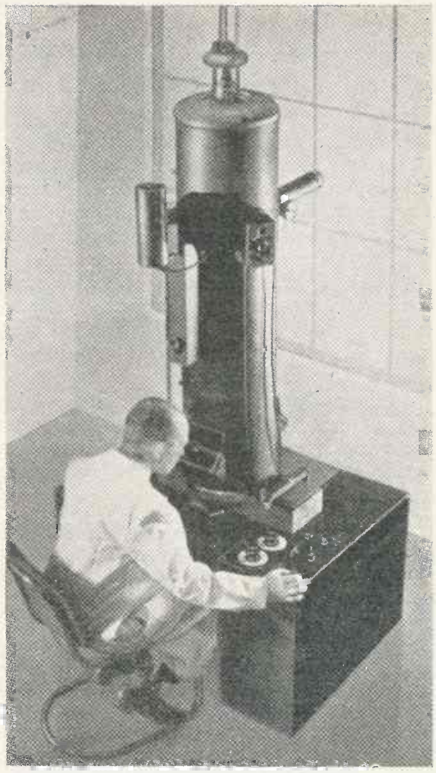
Use of the new electron microscope in the field of biological research may make possible a better understanding of bacteria and the observation of unfiltrable viruses and other similar bodies to which are attributed many human illnesses. In addition, it should become an instrument of great usefulness in many industries; for example, in the study of organic and inorganic materials for many purposes, and in industrial colloidal chemistry in which are involved phenomena produced by extremely small particles which cannot be seen by the optical microscope.

The useful magnification of the finest optical microscope possible is limited by the wavelength of light. Many objects including some bacteria and viruses are much smaller than the wavelength of light, and cannot, therefore, be seen with light. The wavelength of electrons travelling at high velocity is only a minute fraction of the wavelength of light. The electron beam utilised in the R.C.A. microscope has a voltage of from 30,000 to 100,000, and measures only one-one-hundredth-thousandth of the wavelength of light.

A glass lens is nothing more than a means for bending light in a special way so that it forms an image. A magnetic field can be used to bend an electron beam in the same way that a glass lens bends light.

In the electron microscope a magnetic lens system is created which has the same kind of effect on an electron beam that a glass lens has on light.

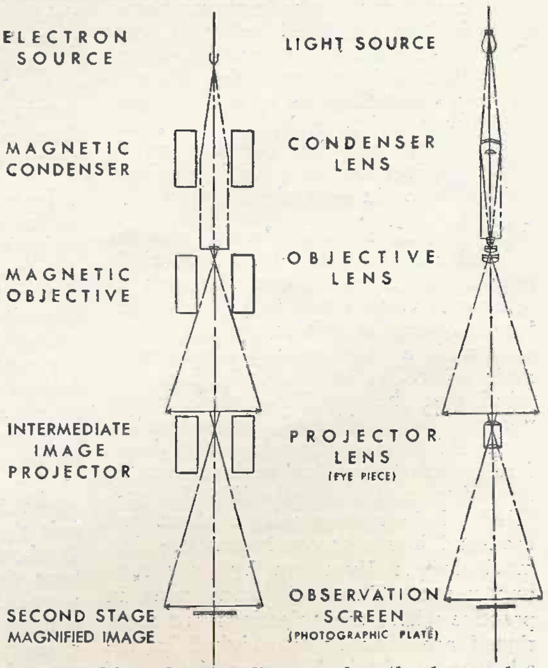
The electron beam, which originates from an electron gun, is converged by a magnetic lens coil corresponding to the condenser lens in an optical microscope in such a way that it passes through the specimen under observation. The electron rays are then focused by another series of lens coils to form the highly magnified image, which can be made visible by causing it to strike a fluorescent screen.



The size of the instrument can be judged from this picture.

This electron image may also be directed upon the emulsion of a photographic plate to make a permanent record of the image. The detail in the resulting photograph is so great that it can be photographically enlarged many times in order to reveal

(*Continued on next page*)

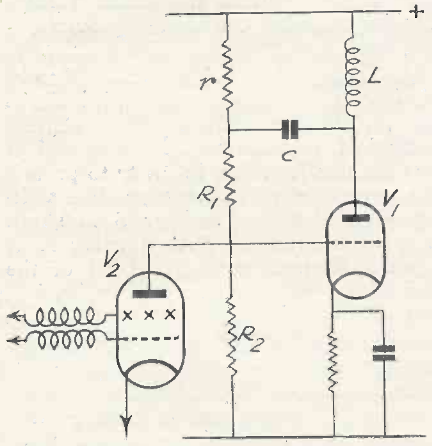


Figs. 2a and 2b. These two diagrams show the close analogy between the electron microscope and the conventional optical instrument.

A Linear Sawtooth-Current Generator

A SIMPLE form of generator of sawtooth currents for operating the deflecting coils of cathode-ray tubes is one in which the coils are placed directly, or effectively so by means of a transformer, in the anode circuit of a valve of comparatively low impedance whose control grid is maintained at a constant potential in the conducting region during the forward stroke of the sawtooth and in the non-conducting region during the return stroke, which is of resonant nature.

An arrangement of this kind forms the basis of the sawtooth-current generator indicated diagrammatically in the accompanying drawing. Here V_1 is the valve referred to and the inductance L represents the scanning coils. Disregarding the presence of the condenser C the operation of the circuit during the forward stroke is somewhat as follows: The valve V_1 and the inductance L constitute in effect the series connection of an inductance and a resistance across the supply, the resistance being that included in the circuit by reason of the valve and also to some extent of the inherent resistance of the coil windings. If the supply voltage is E and the effective series resistance is S the current *i* in the inductance L satisfies the well-known differential equation.



Basic circuit of linear sawtooth-current generator.

$$L\frac{di}{dt} + iS = E,$$

to which the solution is

$$i = \frac{E}{S}\left(1 - e^{-\frac{St}{L}}\right),$$

representing an exponential form of sawtooth, that is to say, a sawtooth that commences the forward stroke linearly, but progresses with an always decreasing slope.

The circuit arrangement shown in the figure constitutes an improvement over that just described insofar as by virtue of the condenser C and the potential divider formed by the resistances R_1 and R_2 feeding on to the control grid of the valve V_1 a certain fraction of its anode potential the rate at which the slope diminishes may be greatly reduced. The improvement arises because as the anode potential of the valve rises corresponding to a diminishing slope, the control grid of the valve is made more positive, so having a correcting effect.

The effect of this feedback may be represented in the original differential equation by writing

$$S = R + KL\frac{di}{dt},$$

giving to a close degree of approximation for the new solution

$$i = \frac{E}{R}\cdot\frac{R + KE}{R}\left(1 - e^{-\frac{R}{L}\cdot\frac{R}{R + KE}t}\right).$$

The current is therefore still of the same exponential form, but the supply voltage has been effectively increased and the time-constant of the circuit likewise. The characteristic is therefore a more linear one, and of greater linearity the greater the feedback fraction K. Alternatively the same degree of linearity is provided with a smaller effective inductance in the anode circuit. One advantage is that a reduced supply voltage may be used.

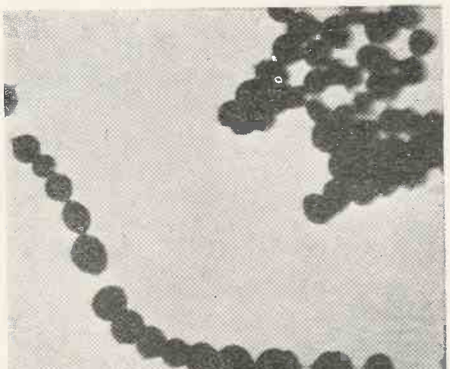
The resistance *r* in the figure is present simply for the purpose of supplying anode current to the blocking oscillator valve V_2 whose function is to carry the grid of the valve V_1 into the non-conducting region during the flyback period, though it is not necessary to use the blocking oscillator valve, provided other means are provided for achieving the same end. In the arrangement shown, the values of the condenser C and resistance *r* may be so chosen that the potential feedback from the anode of valve V_1 is independent of the presence of inherent resistance in the coil L, so that a control strictly proportional to the slope of the scanning current is obtained. The values of C and r are correctly related when the product of r with the coil resistance is equal to the ratio of the coil inductance L to the capacity of the condenser C.

"A New Electron Microscope"

(Continued from preceding page)

all the useful information it contains.

The ordinary glass slides used for examining specimens under the optical microscope are opaque to the electron microscope and an entirely different technique for preparing and handling specimens has therefore been developed. This work was pioneered by Dr. Marton. The specimen is placed upon a film of nitrocellulose only one-millionth of a centimeter thick which is stretched over an extremely fine wire mesh.

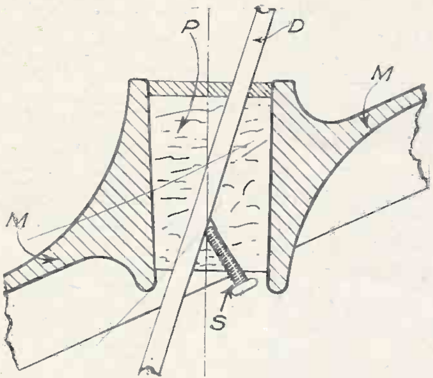


Electron microphotograph of streptococcus hæmolyticus magnified 25,000 diameters.

Since even air is composed of vast numbers of large molecules that hinder the passage of the electron beam, the interior of the microscope is evacuated of all air by a vacuum pump. The specimen is introduced into the microscope through a specially designed air lock that in action resembles the escape chamber of a submarine. A somewhat similar airlock chamber is used to introduce the photographic plate. A special set of gears and screws permit easy movement of the specimen from the exterior, so that every portion of it may be observed at will.

Fig. 1 shows a simplified vertical section of the microscope; as can be judged from the photograph of the instrument in use, it is of considerable size. Figs. 2a and 2b show the close analogy between the electron microscope and the usual optical type. Suitably formed magnetic fields take the place of conventional glass lenses, and a beam of electrons travelling at high velocity (at voltages of from 30,000 to 100,000) takes the place of ordinary light. The electron rays are converged by a condenser lens on to the specimen. After passing through the specimen, the objective lens coil forms a first image, enlarged about 100 times. The projection lens coil then magnifies the image again about 250 times, making an overall magnification of 25,000.

take a wooden plug P. This is bored to take the dipole D, the hole being set at a slight angle so that the aerial projects vertically above the slope of the roof. The dipole rod is held firmly in position by a screw S.



Dipole aerial mounting, Patent No. 521,711

Alternatively, the tile can be used to accommodate the support for an ordinary aerial, or to pass the down-lead from it directly into the house.—*Kolster-Brandes, Ltd.*, and *W. A. Beatty*.

Measuring the Colour of Light

(Patent No. 522,028.)

It is sometimes necessary, particularly in photograhpy, to know what proportion of the primary colours, say red, yellowish-green, and blue, are contained in a given type of illumination. As shown in the Figure, the light from a lamp L is analysed in this way by means of three photo-electric cells, P, P1, P2 each of which, in combination with its filter F, F1, F2, is equally sensitive to a selected one of the three colours in question.

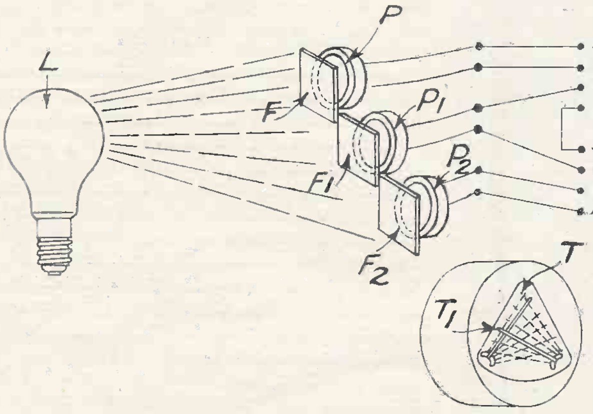


Photo-electric measurement. Patent No. 522,028

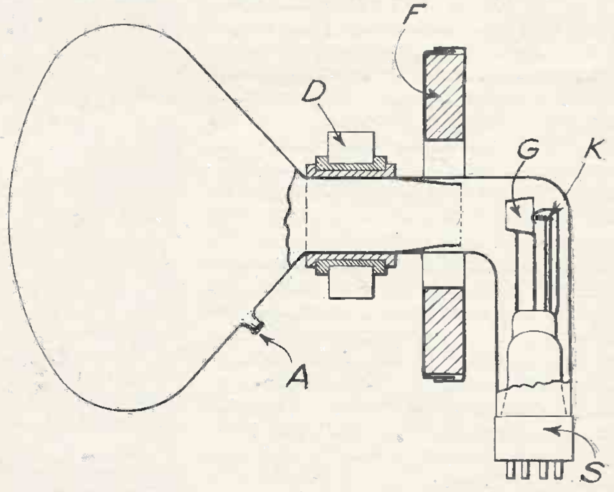
The output from the cells is fed to quotient meters M1, M2 of known type. The meter terminals are connected as shown, so that if the lamp L gives a standard white light (for example a Gibson light) the two indicator needles T, T1 will intersect in the middle of the scale. Otherwise they will intersect to one side or other of the centre, as shown in the separate figure. The indicator scale is suitably calibrated to indicate which particular colour-component predominates.—*I. G. Farbenindustrie Akt.*

Short C.R. Tubes

(Patent No. 522,533.)

The length of a cathode-ray tube proves somewhat of a handicap when it has to be housed inside the cabinet of a television receiver. As shown in the Figure, this drawback is overcome, at least to some extent, by bending the end of the tube containing the cathode and "gun" electrodes at right-angles to the main stem, so that its overall length is reduced.

The flared end of the tube, containing the fluorescent screen, is coated with metal to which an external high voltage connection is made at A. The cathode K and control electrode G are mounted in the socket S so as to direct the electron beam through a focusing-coil F and the usual deflecting-coils D on to the fluorescent screen.—*Kolster-Brandes, Ltd.*, and *C. N. Smyth*.



Method of reducing length of cathode-ray tube. Patent No. 522,533

A Summary of Other Electronic Patents

(Patent No. 512,999.)

Arrangement for ensuring accurate synchronisation of the framing periods in an interlaced scanning system.—*Baird Television, Ltd.*

(Patent No. 513,640.)

Design and assembly of the electrodes in a cathode-ray tube, particularly the cathode or "gun" structure.—*Standard Telephones and Cables, Ltd.; F. D. Goodchild; D. H. Black and C. H. Foulkes.*

(Patent No. 513,693.)

Cathode-ray screen with different dispersive characteristics for modulating a ray of light projected from an external lamp on to a viewing screen for television.—*Scophony, Ltd., and A. H. Rosenthall.*

(Patent No. 515,567.)

Cathode-ray indicator for detecting the presence of an aeroplane or other moving object obscured by cloud or fog.—*E. G. H. Mobsby and C. G. Slazenger.*

(Patent No. 516,047.)

Rectifier for supplying constant voltages to the electrodes of an X-ray tube. — *N. V. Philips Gloeilampenfabrieken.*

(Patent No. 517,666.)

Television amplifier designed to allow one programme to be faded out in favour of another.—*Philco Radio and Television Corporation.*

(Patent No. 513,155.)

Method of mounting and aligning the electrodes of a cathode-ray tube. —*The General Electric Co., Ltd., and R. H. Craig.*

(Patent No. 514,401.)

Controlling the "picture contrast" in a television receiver by the use of negative feed-back.—*Baird Television, Ltd.*, and *T. C. Nuttall.*

(Patent No. 514,509.)

Separating the synchronising impulses in a television receiver by a method which is not handicapped by the presence of the D.C. or "background" component of the picture signals.—*Marconi's Wireless Telegraph Co., Ltd.*, and *D. J. Fewings.*

" Modern X-Ray Apparatus and Its Applications "

(*Continued from page* 394)

This low vapour tension is a necessary feature of all the metals used in the electrodes because of the necessity of maintaining a high vacuum in the tube under all conditions of operation. This, of course, applies to all high-vacuum tubes, and for this reason also metal of a high degree of purity must be used and great care taken during the evacuation of the tubes to release all occluded gases.

The filament is usually a faily thick pure tungsten wire spiral. The modern method of focusing is that of the line focus principle (*see* Fig. 3). In this diagram the line focus principle is seen combined with a rotating anode, but it is used in the same manner with a stationary anode. By utilising this method a large source of electrons is made to produce a more concentrated beam of X-rays without the loss of definition associated with a diffused focal spot.

Some tubes employ a twin line focus, that is, a long and a short filament which can be used alternatively as desired. This is a useful asset when a tube is used to perform many different types of work. The fine focus is used for work needing great detail as in radiography of the structure of the bones, and the larger focus is used tor less accurate work or when a larger output is desired from the tube as the thermal dissipation is improved when using the larger focus.

Shielding

Various metallic shields and hoods are introduced into the design of the electrodes to shield them from stray electronic bombardment.

Metal to glass seals have been improved to allow for present day working conditions and other features introduced to relieve the glass tube of the enormous electrostatic strains imposed upon it.

4. T*he Prevention of Stray Radiation*: In the early days X-ray tubes emitted X-rays in every direction and were placed in lead boxes or lead glass bowls to prevent the unwanted rays from reaching the subject or the operator. In modern tubes, although the rays are still given out in every direction, the unwanted rays are stopped close to their source by surrounding the tube with metallic sheaths in the region of the anode and allowing only a small window through which the needed rays may emerge and be more easily controlled. In addition other protective devices are also incorporated in the associated apparatus for further control of the rays after they have left the tube.

The Rotating-anode Tube

Although the greater number of tubes in use to-day are of the stationary anode type, during the last few years the rotating anode tube has been developed to meet the desire for a tube giving a very large output for a short period such as is necessary in radiography of the heart, as the normal movement of the heart produces some blurring of the radiograph during an ordinary exposure. They are also used for continuous screening, the great improvement in heat dissipation of the rotating anode being the main feature in the design for continuous operation.

In one type (*see* photographs and Fig. 3) the anode consists of a bevelled tungsten plate attached to a spindle which runs on ball bearings at a speed of 2,700 r.p.m. All this assembly is inside the evacuated tube. The cathode is fixed and placed eccentrically relative to the anode plate as shown.

Therefore only a small part of the track (6) is heated by the cathode stream during one revolution and this part is enabled to cool off during the remainder of the revolution.

The average diameter of the track is 6.7 cm. and thus during an exposure of 0.1 second 95 cm. of track will be traversed by the focus of the cathode stream. A comparison of the effective area of this cooling with that of the stationary anode demonstrates the ability of this type of tube to handle a high milliamperage. By providing such improved cooling the focus can still be kept small in size in spite of the higher currents being passed.

The anode and its spindle are caused to rotate in vacuo by a rotating magnetic field induced through the glass walls of the tube. The field is provided by a stator winding surrounding the tube near the end of the spindle and fed from 3-phase current. The development and perfection of the rotating anode tube is a very fine example of electronic engineering technique.

Tubes for use in deep X-ray medical therapy have been developed to work on voltages up to a million and with which a great deal of research is still being carried out. As an example, one of these in use is some thirty feet in length. As it is too large to be moved conveniently relative to the patient, the patient is placed on a motor-driven adjustable couch instead.

All parts of the tube are detachable for replacement and adjustment of the electrodes, etc., and the vacuum is continuously maintained by means of high vacuum pumps. The central part of the tube occupies one large room and either end projects into a large building on either side containing the H.T. generators. The controls and operators are housed in a separate room, heavily screened from stray radiation, and the patient is observed through a periscope system whilst the tube is in operation.

LIGHTING BY FLUORESCENT POWDERS

The use of fluorescent powders in cathode-ray tubes for producing visual effects has been dealt with in many papers. Another application of the property of fluorescence, namely in signs and decorative effects, is discussed in a paper which was read before the Illuminating Engineering Society. The following is an abstract*

THE fluorescent materials used in signs and illuminated lettering are usually exposed to the ultra-violet light emitted by one of the well-known mercury vapour discharge lamps enclosed in "black" glass bulbs. These lamps emit a long wave ultra-violet radiation which excites the fluorescent powder by the absorption of the radiation between certain narrow limits. There is a definite wavelength at which the energy absorbed is converted into visible light with the maximum efficiency, lying at approximately 3,650 A for zinc sulphide phosphors.

The luminescent materials which are in general use at the present time for producing luminescent lighting effects may be conveniently classified in three groups :—

Class A—Zinc and zinc-cadmium sulphide phosphors.

Class B—Alkaline-earth sulphide phosphors.

Class C—Fluorescent organic materials.

The materials in these three classes differ from one another in both their nature and uses. They are all excited by long wave U.V. energy so that convenient, safe sources are suitable for their excitation.

Class A—Zinc and Zinc-Cadmium Sulphide Phosphors.—Luminescent materials of this class are produced as fine crystalline powders and require to be mixed with a suitable vehicle to form a paint. They provide a wide colour range and a high luminescent brightness and are particularly applicable to decorative and display purposes. Where a phosphorescent effect of about one-hour's duration is required, certain members of this class are suitable.

When correctly applied in paint form they have a good durability under all normal conditions of both interior and exterior use. They are, however, relatively costly to produce and are not very suitable for applying to fabrics.

Table I. Effect of Backing on Brightness of Zinc Sulphide Paint (0.5 oz. per sq. ft.).

	Backing	Percentage increase over brightness of unbacked paint
1.	Silvered Glass Mirror ..	20
2.	Stainless Steel	10
3.	Pot Opal	25
4.	Bristol Board	25
5.	Leadless White Paint ..	25

Class B—Alkaline-earth Sulphide Phosphors.—When a long afterglow, maintaining a useful brightness for about twelve hours, is required, the alkaline-earth sulphide phosphors are particularly applicable.

These are similar to Class A materials in their general form and methods of use. Paints incorporating Class B materials tend to be less durable than those of Class A, particularly under outdoor conditions.

Owing to the tendency of alkaline-earth sulphides to hydrolyse with the evolution of hydrogen sulphide, it is necessary to use a vehicle which is especially resistant to moisture when making these phosphors into paints. In general, a vehicle suitable for Class A phosphors is not suitable for those of Class B and vice versa.

Class C—Fluorescent Organic Materials.—Many organic compounds can be prepared as fluorescent lacquers or dyes, and some of them are useful to the illuminating engineer for display and decorative effects. In general, organic materials have a lower fluorescent brightness than sulphide phosphors.

The brightness of a luminescent material is a function of the coating density or concentration of the material, i.e., its weight per unit area, the reflection from any surface on to which it is coated, the intensity of irradiation, and the temperature of the material. Any deterioration of the luminescent properties with life will also affect the brightness.

With phosphors of Classes A and B, when the paint is sprayed on, there is a rapid increase in brightness with increase in phosphor concentration at first, but this becomes progressively less for equivalent increases in weight.

Phosphor concentrations of 0.5-0.8 oz./sq. ft. represent economic "optimum" weights, the actual value selected being an arbitrary compromise between brightness and cost.

When the maximum brightness is desired from the luminescent surface on which the exciting radiation falls, light which is transmitted by the paint can be utilised to increase the brightness by the provision of a reflecting backing. The degree of increase due to the backing is naturally dependent on the thickness of the material, decreasing as the thickness increases. At the concentrations generally recommended for practical use, the increase in brightness is nevertheless sufficient to make

(*Continued on page 431*)

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* Harper, Robinson & Bowtell, Trans. Ill. Eng. Soc., Vol. 5, No. 5, p. 57. June, 1940.

Class A and Class B, using specially developed protective media. If media not specially developed for this protective purpose are used a much more rapid deterioration will occur.

When phosphors are irradiated they do not reach maximum brightness immediately radiation falls upon them. The process is a progressive one, the rate of excitation and the resultant growth in brightness being determined by several factors, including the nature of the phosphor and the intensity of irradiation.

The process appears to be closely associated with the corresponding phenomenon of phosphorescence. Phosphors which have only a short afterglow rapidly reach maximum brightness; those having a long afterglow require to be irradiated for a longer time before they are fully excited.

The period of growth to the maximum brightness varies from small fractions of a second for fluorescent materials to several minutes for the alkaline-earth sulphides when irradiated by a 125-watt

Table 2. Effect of Deterioration with Life on Brightness of Luminescent Materials.

Phosphor	Undercoat Backing	Protective Coats	Exposure Details	Percentage Decrease in Brightness
1. Zinc Sulphide (Green luminescence)	White Paint on Wood	1 overcoat	Exposed for five Winter months in unprotected position outdoors	20
2. Zinc - cadmium Sulphide (Orange luminescence)	White Paint on Wood	1 overcoat	Exposed for five Winter months in unprotected position outdoors	20
3. Alkaline - earth Sulphide	White Paint on Wood	2 sealing coats; 3 overcoats	Exposed for three Winter weeks in unprotected position outdoors	20
4. Alkaline - earth Sulphide. (Note: Brightness greater and stability lower than 3)	White Paint on Wood	2 sealing coats; 3 overcoats	Exposed for four Winter months in unprotected position outdoors	50

"Wide-range U.H.F. Receiver"

(*Continued from page* 417)

characteristic. A double resistance-capacity filter circuit is used, with one set of RC values to respond to rapid voltage variations while the other responds to slow changes.

As all standard F.M. broadcast transmissions have greater modulation with increasing audio frequency, a de-emphasis circuit having a time constant of 100 micro-seconds and consisting of a series resistance of 0.1 megohm and a shunt capacity of 0.001 $\mu\mu$fd. are used as shown (R_{19} and C_{13}, Fig. 4).
