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Röntgenology

NOVEMBER 8 marks the fiftieth anniversary of the discovery of X-rays, the first and perhaps the most important electronic phenomenon. And yet in spite of its importance there are very few electronic engineers who have more than a superficial acquaintance with the technique and application of modern X-ray equipment.

As Dr. Mullins describes on another page, the field of radiography is no longer confined to the medical profession, but is being rapidly extended to all industrial fields, and the X-ray tube can now claim to rank with the cathode-ray oscillograph as an indispensable aid to the testing and examination of products.

Some of the more spectacular advances in X-ray technique have been reported in the medical papers, and for this reason the engineer may not be aware of the trend of modern practice, nor, more important, may he be aware of the scope for improved measuring and timing equipment.

Some of the improved methods of obtaining short pulse timing which have been perfected during the war may find an important application in the accurate control of X-ray exposure times. New fluorescent materials may give rise to improvement in viewing screens, and the great advances in photographic materials are being reflected in greater accuracy and detail in the modern radiograph, even when reduced to the size of 35-mm. film.

As an example of recent improvements in medical radiographic technique, the paper by W. Watson on "Differential Radiography" may be cited.* In this system a distinct difference is produced between a particular plane in an object and the remaining planes by simultaneous movement of the focus of the rays and the film about the plane. His concluding statement shows how close the liaison is between the engineer and the radiographer :

> "... the realisation of the simple theoretical principles of differential radiography is largely a matter of skilled mechanical engineering. Whether the apparatus achieves success or not depends on the way it is used, and since this calls for skill and experience the radiographer must begin where the engineer leaves off—not that the engineer ever does."

Thank you, Mr. Watson. The engineer will never leave off as long as his skill and experience can be of help in improving the oldest electronic device which has been of such immense benefit to mankind.

* *Radiography*, Vol. 5, No. 54, June, 1939.

Commemoration Programme on the Discovery of X-Rays

A series of meetings will be held between November 8 and 10 to commemorate the discovery of X-rays. The programme has been jointly planned by a large number of scientific societies, and includes, among other meetings—

A Joint Meeting of the participating societies on Friday, Nov. 9, at 3.30 p.m., at

The Phœnix Theatre,
Charing Cross Road, W.C.2.

Chairman
Sir Henry Dale, O.M., F.R.S.

Speaker
Sir Lawrence Bragg, O.B.E., F.R.S.,
on

The Scientific Consequences of Röntgen's Discovery of X-Rays

Scientific meetings dealing with the application of X-rays to industry, physics and chemistry will be held at the Royal Institution and The Institution of Electrical Engineers.

There will also be a small exhibition of historical apparatus at the Reid Knox Hall of the Institute of Radiology.

Further information can be obtained from the Secretaries of the learned societies participating:

The Royal Society
The British Institute of Radiology
The Faculty of Radiologists
The Hospital Physicists Association
The Society of Radiographers
The Mineralogical Society
The Physical Society
The Chemical Society
The Royal Photographic Society
The Institution of Electrical Engineers
The Faraday Society
The Institute of Physics

Electronic Engineering

NOVEMBER, 1945

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Radiograph of skull, showing embedded bomb fragments. Exposure time, 1 second

In order to appreciate the advances in X-ray technique it should be noted that the exposure time required in 1895 would have been several hours. In 1914 a similar war injury would have required 25 sec. exposure. As the potential danger to the patient is an inverse function of the exposure time and current, the safety of radiography has been increased over twentyfold during the past 25 years.

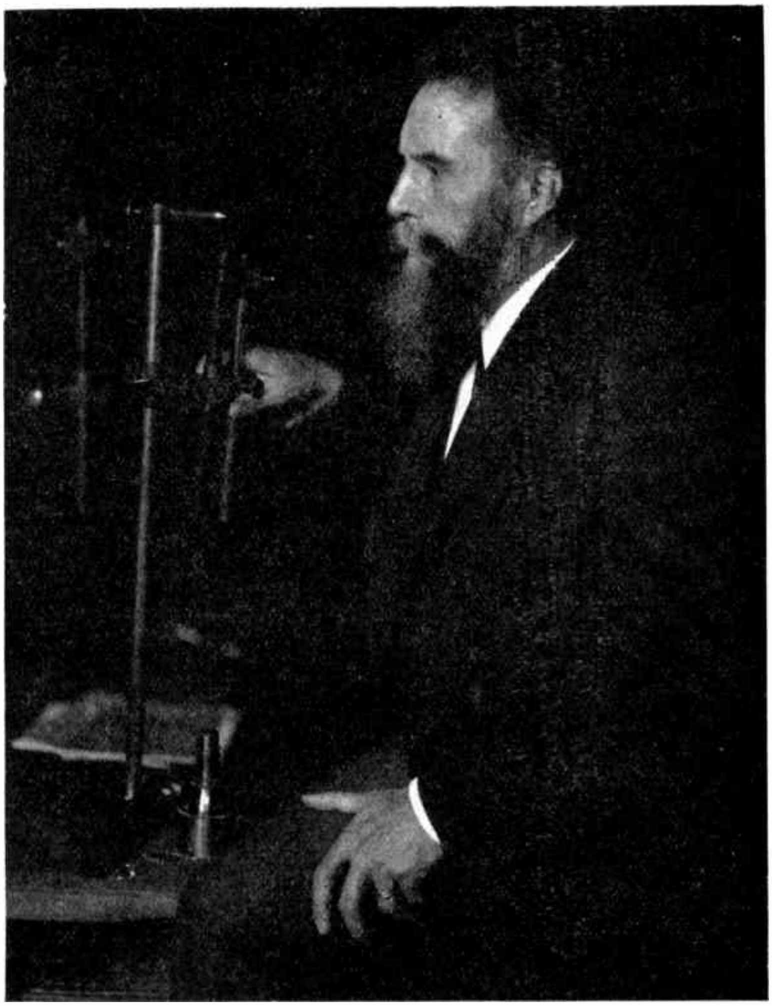
—Photograph by Ilford Radiographic Laboratory

The Discovery of X-Rays

By

J. A. CROWTHER*

M.A., Sc.D., F.Inst.P.



Wilhelm Konrad Röntgen, 1845 — 1923

FIFTY years ago, in November, 1895, Wilhelm Konrad Röntgen, Professor of Physics in the little University of Würtzburg in Bavaria, startled the local Physico-Medical Society of the town with the announcement that he had discovered a new type of radiation, capable of passing through materials which were quite opaque to ordinary light. The news spread like wild-fire. The possibility of being able to "see" into a closed cardboard box, or through a stout wooden door, was just the sort of thing to excite the interest of a public not yet satiated with scientific marvels; and X-rays, as their discoverer modestly called them, became the talk of the town. Paragraphs got into *all* the papers. Not only did *Nature* print a translation of Röntgen's original paper in January, 1896, but only a couple of months later its more vivacious contemporary, *Punch*, made it the subject of a cartoon. The discovery even obtained recognition in the Music Hall, that ultimate touchstone of popular fame, where comedians were not slow to envisage some of the more embarrassing possibilities of the "New Photography" as it was popularly called.

"They can photo you going to bed from the street,
Through your boots they can snapshot the size of your feet.
They've got you while spooning your girl (oh! so sweet)
In whatever position you be.
If to kid folks you dined upon pheasant you've tried
When the new camera to your chest is applied
It brings out a full view of the kipper inside
By the New Photographee."

As is usual with any new scientific discovery the potentialities of the new radiation were a little exaggerated. Some of the forebodings—or, maybe, hopes—expressed in the song were not to be realised; but at any rate, for the first time, physics was definitely on the map.

The scientific world was equally stirred. Physics had been passing through a sticky period. It was felt, quite generally, that with the Kinetic Theory of Gases, and with Clerk Maxwell's great electromagnetic theory of light the ultimate mysteries of nature had been reached, and that nothing remained, for future experimenters, but the tedious process of "putting another decimal point" on to all the physical constants; and clearing up a few untidy corners. The discovery of X-rays opened up an entirely new field of research, gave a new direction to physical science, and initiated that era of hitherto undreamed of discovery and invention which, progressing with ever-increasing momentum and ever-widening scope, has culminated (let us hope not finally and catastrophically) in the atomic bomb. Rayleigh in his

* Professor of Physics, University of Reading.

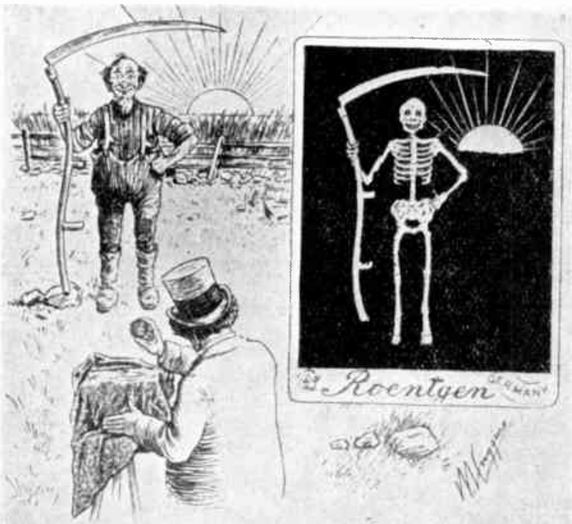
recent biography of Sir J. J. Thomson (who eighteen months later was to discover the electron) writes: "The great turning point (*i.e.*, in Thomson's career) was the discovery of X-rays by Röntgen. We shall see presently how this led to a great outburst of activity in the Cavendish Laboratory." The same might equally have been written of other centres of research. Becquerel, for example, imagining that the new radiation might be a sort of by-product of the fluorescence in the electric discharge, set out to investigate if naturally fluorescent materials also emitted this new type of radiation, and so stumbled upon the activity of Uranium. The isolation of radium by the Curies followed. The Science of Radioactivity was born—a direct, if illegitimate, offspring of Röntgen's new rays.

The apparatus with which Röntgen made his discovery was of the simplest: just a Crookes tube, or diode, with a cathode at one end and an anode tucked somewhere out of the way, exhausted to what, for those days, was the low pressure of some tenths of a millimetre or so of gas. It was fed by an induction coil capable of giving at best a mere trickle of current at some fifty kilovolts. A piece of cardboard carrying a few crystals of barium platinocyanide (a substance in common use for detecting, by its fluorescence, the ultraviolet rays in the spectrum) completed the outfit. In order to cut off all visible and ultraviolet light, the Crookes tube was completely wrapped up in black paper. Nevertheless, whenever an electric discharge was passed through the tube, the crystals of the primitive fluorescent screen responded with their customary green-yellow glow. *Something* was coming from the tube which was capable of exciting the crystal, in spite of the intervening opaque wrappings. X-rays had been discovered.

It was as simple as that! Almost anyone could have done it. Not only was the elementary apparatus required available in every physical laboratory; Röntgen's identical "set-up," with the exception of the all-important fluorescent screen, was actually in operation in a number of research departments; the physics of the electric discharge being a rather fashionable subject of research at the time. As early as 1883 Crookes himself had melted platinum by focusing a beam of cathode rays on a small platinum target *in vacuo*; an arrangement which must have given a far larger output of X-rays than Röntgen's primitive tube. Sir J. J. Thomson used to relate, with that infectious chuckle of his which so

The early fallacy that X-rays would enable actual photographs of concealed objects to be taken gave rise to several humorous drawings of this type.

Below: *Life*, 1896. Right: *Punch*, 1896.

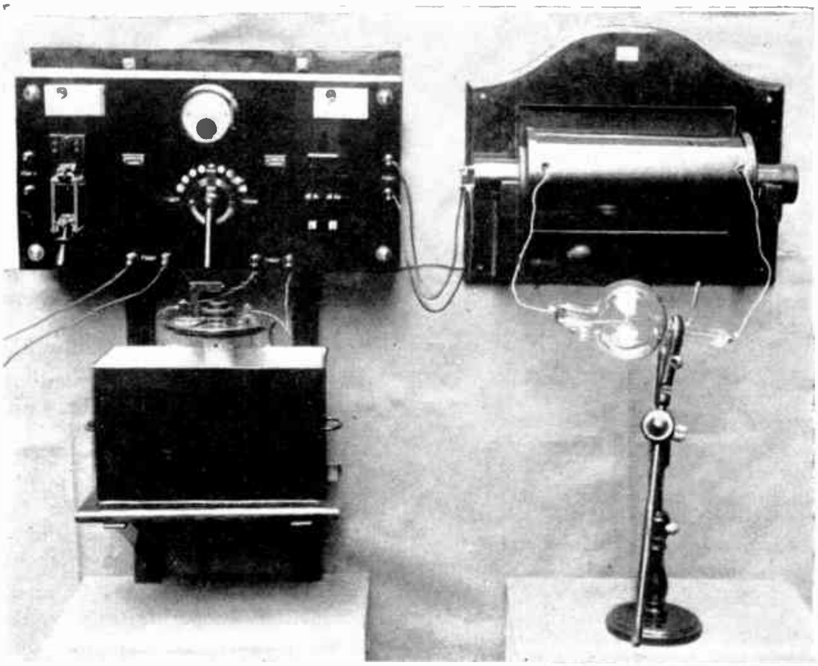


THE NEW ROENTGEN PHOTOGRAPHY.
"LOOK PLEASANT, PLEASE."

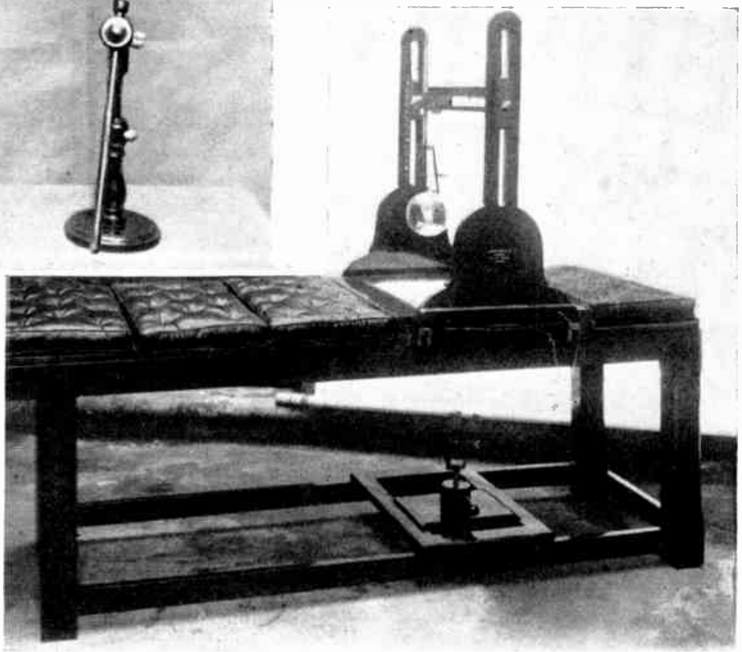
MARCH 7, 1896.] PUNCH,

THE MARCH OF SCIENCE.

INTERESTING RESULT ATTAINED, WITH AID OF RÖNTGEN RAYS, BY A FIRST-FLOOR LODGER WHEN PHOTOGRAPHING HIS SITTING-ROOM DOOR.



endeared him to his students, the story of the eminent physicist (he would never give the name) who had found that photographic materials kept in the same room as his Crookes apparatus became badly fogged, as if by stray light. As, however, the trifling annoyance could easily be overcome by removing his stock of plates to another room, he had given the matter no further thought. The possibility of the existence of radiation with the properties of X-rays was, in fact, so remote from current

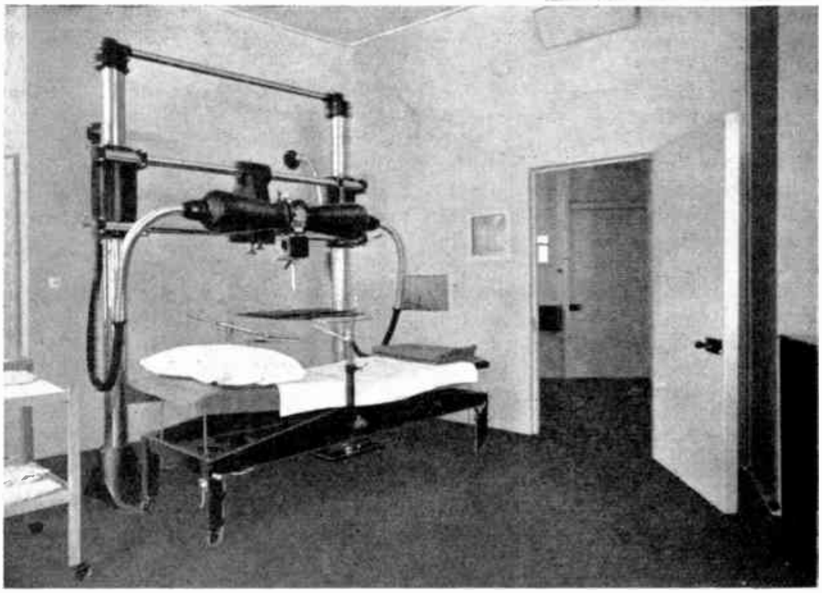


The Old and the New.

Above : The original installation at the London Hospital Receiving Room, and (right,) the couch made for Dr. Mackenzie Davidson.

Below : Modern X-ray examination couch, with shock-proof metal-enclosed tube.

— Photos by courtesy of Newton & Wright, Ltd.



scientific thought that no one—except Röntgen—thought of looking for it. It was this single flash of inspiration which won for Röntgen his imperishable niche in the gallery of science, and flung wide open the doors of a new era.

The story of the discovery of X-rays is, perhaps, not without its moral for an age in which the clamour for the planning and control of scientific research is becoming vociferous, and utility is being claimed to be its only legitimate motive. Nature is full of surprises, and both science and society will be the poorer if we cannot keep a place for the lone experimenter who prefers to follow some private inspiration of his own, rather than to tramp along the road marked out for him by the pundits of the age. Röntgen was not the first experimenter who has left the beaten track, and stumbled on Eldorado.

What line of thought, if any, led Röntgen to his discovery is not known. "What did you think when the crystals glowed?" the great English surgeon, Mackenzie Davidson, asked him a few months later. "I did not think," Röntgen replied, "I made experiments." The fact that he labelled his radiation "X"—the great unknown—seems to indicate that he had not speculated as to its nature. And yet the explanation of the origin of X-rays had been waiting for verification for fifty years. It was contained in the remarkable letter written by Michael Faraday to the Editor of the *Philosophical Magazine* in 1846. This letter was so much in advance of the age that twenty years later Faraday's biographer, Tyndall, half apologises for it, on the grounds that the old philosopher was just recovering from a nervous breakdown. Suppose, wrote Faraday, that we have an electric charge with a line of force (Faraday tube) attached to it at A, and we suddenly move it to B; shall we not develope a kink in the line of force, and will not this kink travel out along the line? But this was precisely what Röntgen had been doing in his classical experiment. He had been moving electric charges, with very high speed, from his cathode A to the walls of his Crookes tube, B. X-rays were just the sharp kinks produced in the lines of force by the sudden stoppage of these charges. Faraday's letter, as everyone now knows, was developed by Maxwell, into the electromagnetic theory of light. The elegance of Maxwell's mathematics had, perhaps, rather obscured the fundamental simplicity of Faraday's original idea. This was now revived by Stokes, at a meeting of the Cambridge Philosophical Society in March, 1896, and was, after much discussion, finally accepted. The peculiar properties of the radiation were to be ascribed to the sharpness of the kinks, or, in other words, to its extremely short wavelength.

Nearly twenty years were to elapse before Stokes's theory received full confirmation, by actual determination of the wavelength of X-rays. It was not thought possible at the time that any grating could be devised sufficiently fine to produce with X-rays those diffraction effects which we rely upon for determining the wavelength of any electromagnetic radiation, though this has since been achieved by Compton. It was not until 1912 that Laue conceived the brilliant idea that the orderly arrangement of the atoms in a crystal might serve the purpose, and that any mineralogical collection would provide X-ray gratings by the handful. Two of his colleagues (Laue himself was a mathematician) verified the suggestion, and produced the first X-ray crystal diffraction photograph. The following year Bragg, by a combination of physical optics, geometry and inspiration was able to give an actual figure for the wave length of X-rays, and incidentally, to fix the position in space of every atom in the crystal he was using for the work. This ability of the radiation to enable us to fix the actual arrangement of the atoms in a crystal has given a new impetus and new certainty to the study of the solid state, and X-ray crystallography is now a considerable science, in its own right. It is proving invaluable in industrial research, and no up-to-date laboratory is regarded as complete without an X-ray spectroscope.

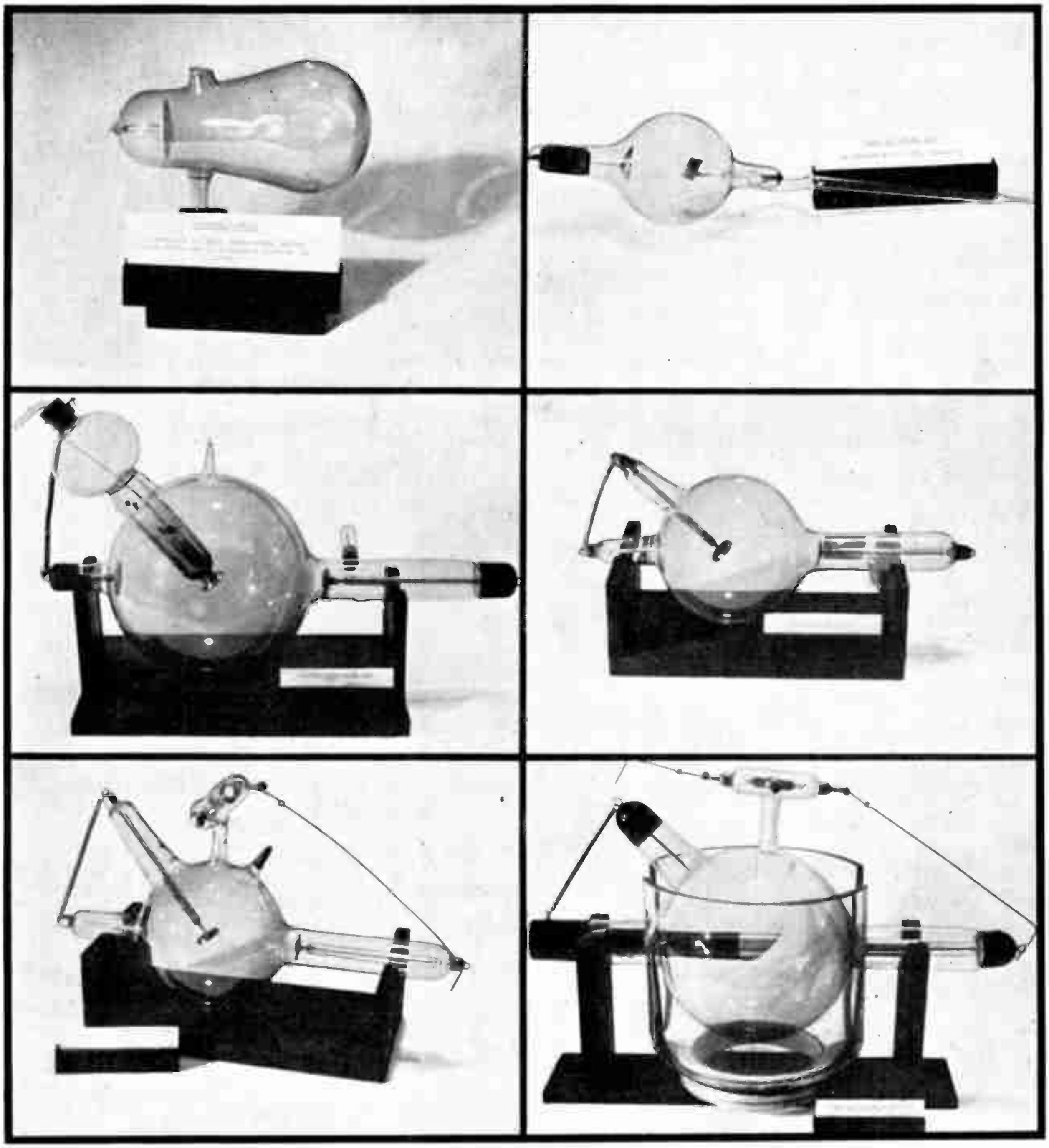
No account of the early days of X-rays could be complete without at least a passing tribute to the great part played by the medical profession in the development of the subject. Even to-day, when an acquaintance tells us he has "had an X-ray," we assume that he has been in the hands of a medical radiologist. From the moment when Röntgen made the first radiograph, by firing the rays through the door of his laboratory, and discovered on the photographic plate well-defined shadows cast by the concealed white lead cement with which an ornamental beading had been attached to it, the possibilities of the radiation as a means of diagnosis were apparent. The idea was taken up with avidity by medical men (incidentally, industry took about twenty years to tumble to the idea) and nowhere with greater keenness and success than in this country. With apparatus as make-shift as Röntgen's own, in cellars and improvised dark rooms these possibilities were explored and exploited. The destructive effects of X-rays on human tissue had, unfortunately, not been foreseen, and not a few of these pioneers paid for their enthusiasm with their lives. It is well that we should pause for a moment, on this fiftieth anniversary of the discovery of the radiation, to remember them. That the radiation might also be employed to combat disease was not so evident; nevertheless, it was tried, and tried with such success that radiotherapy now offers by far the best hope of alleviation or cure for some of humanity's most dreaded scourges.

When one recalls the inadequacy of the apparatus with which this pioneering work was done, one marvels at the perseverance and skill of these early medical pioneers. Even when I began X-ray experiments (if one may be permitted a personal reminiscence ten years after Röntgen's discovery) I remember distinctly sitting, my eye glued to a microscope, with a pile of wooden blocks by my side to hurl at the "hammer break" of the induction coil if it stuck, as it generally did at some crucial stago in a measurement.

Gradually the demands of the medical profession (backed latterly by the still more effective demands of industry, which is becoming increasingly X-ray conscious in these days) resulted in vast improvements in the power and convenience of X-ray apparatus. A modern X-ray outfit may weigh three-quarters of a ton or more, is capable of producing radiation at a million volts which will penetrate six inches of armour plate, and can be switched on with little more trouble than is involved in switching on an ordinary electric light bulb. The contrast between one of these obedient "genii of the lamp" and the temperamental assortment of physical apparatus which had to suffice the early experimenters is indeed astounding.

Röntgen's discovery of X-rays has proved to be one of the great germinal discoveries of science; important, not only in itself, but even more so in the further knowledge which it has engendered. Four new sciences, Radioactivity, X-ray crystallography, Radiotherapy, and Radiodiagnosis, derive their existence directly from it, and Radiobiology is a promising infant. To attempt to recount its contributions, direct and indirect, to the progress of physics would be to write the history of a great part of the physical researches of the past fifty years. The faint light which, fifty years ago, flickered on the fluorescent crystals in Röntgen's darkened laboratory has indeed illuminated vast tracts of human activity.

Early X-Ray Tubes



The Growth of Industrial Radiology — Fig. 1.

Top left : **Crookes tube similar to that with which Röntgen discovered X-rays in 1895 (damaged).** *Top right* : **Jackson tube, 1896.** *Middle left* : **Gundelach water-cooled tube, 1906.** *Middle right* : **Cox Record tube, 1913.** *Bottom left* : **Andrews Rapid X-ray tube, 1916.** *Bottom right* : **Andrews 8-inch Leviathan tube, 1926, with lead glass bowl shield.**

—Reproduced by courtesy of Kodak Limited

The Growth of Industrial Radiology

By L. MULLINS, M.Sc., Ph.D., F.Inst.P.*

Summary

Industrial radiography dates from the discovery of X-rays in 1895. Its growth and that of the more recently established science of X-ray crystallography is reviewed, with particular reference to those aspects of interest to the electronic engineer.

THE industrial application of X-rays dates from their discovery, being foreshadowed by Röntgen's extensive experiments which demonstrated almost all the properties of the new radiation. In his epoch-making preliminary communication "On a New Kind of Rays," presented to the Physical Medical Society of Würzburg on December 28, 1895, Röntgen wrote:[1]

"I possess . . . photographs of the shadow of the profile of a door . . . the shadow of a covered wire wrapped on a wooden spool; of a set of weights enclosed in a box; of a compass in which the magnetic needle is entirely enclosed by metal: of a piece of metal whose lack of homogeneity becomes noticeable by means of the X-rays, etc."

What further examples are covered by the term "etc." is not recorded but it is clear that the importance of the new radiation was evident not only in medicine but also in industry. Within a month of Röntgen's communication, A. W. Wright, of Yale University, showed that an X-ray photograph of a weld revealed details otherwise invisible.[2] Immediately U.S. ordnance officials emphasised the significance of this experiment for industry in providing a means of inspecting armour and discovering flaws in machinery.[3] A month later the Pittsburgh Carnegie Steel Works investigated the application of X-ray methods to steel.[2] About the same time both the German and Austrian Ministers of War remarked on the value of X-rays in the inspection of armament.[2] As in the medical field, the new technique caught the public imagination and brought forward whimsical rhymes on X-ray inspection of which the following published in *Life* in July, 1896, is typical:

Patriotism and Science.

Little Willie's cast-iron cannon
Ne'er had felt the roentgen ray;
Perfect was it in appearance
But a flaw was hid away.
Little Willie's bones and muscles,
All were photographed next day,
So they might collect that cannon
Aided by the roentgen ray.

But the serious side was not forgotten and the opinions of far-sighted men were exemplified by the *Electrical World*[4] statement that "we see before us a great field in metallurgy, not only in testing important castings and heavy wrought-iron work without unnecessary fracture, but in everyday work, such as approving of steel rails, armour plates, bridge material, etc., this discovery may be of immense value."

By the end of 1896 X-rays had been used for the examination of parcels suspected of containing bombs,[5] for the inspection of postal packets,[6] for the detection of adulterated foodstuffs,[7] and for discriminating between various types of porcelain[8] and between genuine and faked precious stones.[8] The value of X-rays in the examination of oil paintings was also reported.[9]

These applications are remarkable in view of the extremely crude X-ray generating equipment available. The high voltage was generated by either a static generator such as the Wimshurst machine or by an induction coil. The gas tubes in use were modifications of the original Crookes tubes with which Röntgen first observed X-rays. Many ingenious designs were produced, as illustrated in Fig. 1, page 759, their main features being an aluminium concave cathode with a tungsten or platinum plate target tilted at an angle of 45° to the axis of the tube which contained gas at a low pressure. The focusing anode, which was based on an earlier gas discharge tube designed by Sir William Crookes, served to focus the electron beam on the target (or anti-cathode) so producing a small X-ray source and thus improving image definition. Some designs incorporated a subsidiary electrode which could be connected at will to the anti-cathode, thus assisting the regulation of the tube. One serious limitation was that tube current and applied voltage could not be varied independently. Moreover, the gas pressure dropped in use so that increased potential was necessary to maintain the discharge, with a resulting increase in the penetration or hardness of the radiation. This latter difficulty was overcome by heating the tube or by the "regenerative" tubes which incorporated some device for releasing gas within the tube.

While working on X-ray tubes about this time the ingenious Edison[10] made a fluorescent lamp by fusing crystals of calcium tungstate to the walls of an X-ray tube. Scarcely any X-rays were emitted, the tube giving off a white light, which, according to the inventor, was equivalent to "two and a half candle power."

The generating voltage of X-ray tubes was measured in terms of the spark length between points. Induction coils were available giving spark lengths up to 30 in., but advertisements in 1901 mention no tubes suitable for spark lengths greater than 10 inches. The price for a complete X-ray equipment including an induction coil, X-ray tube and the various accessories varied from about £19 10s. 0d. to £50.

Within a few years the medical uses completely overshadowed all the other possible applications, no doubt due to the lack of sufficiently penetrating rays. Writing in 1901 Isenthal and Ward[11] said:

"Except in thin sections or in small dimensions, most metals are almost opaque to even the most penetrative rays which we can produce with the best and most powerful apparatus."

Nevertheless, there were a few enthusiasts who continued to investigate the industrial uses and great credit is due to these pioneers, beset as they were by the many difficulties and dangers of such work. Unhappily the extent of these dangers was not sufficiently well realised. As early as April, 1896,[12] a so-called sunburn effect was reported and was soon followed by other accounts of the effect of X-radiation on human tissue. According to Glasser,[13] one of Edison's assistants contracted severe burns which proved fatal and this caused Edison to discontinue his experiments with X-rays. There seemed, however, to be some disagreement regarding the cause of these tragic and untoward effects, since some workers suffered no apparent misfortune. In

* Research Laboratories, Kodak Limited, Wealdstone, Harrow, Middlesex.

fact Röntgen suffered no ill-effect from his extensive experiments, but this was probably due to his operating the tube within a zinc box, later interposing a lead sheet between the zinc and his body. These precautions, says Glasser,[14] were probably to assist in defining the X-ray beam and to protect his photographic plates.

At first existing photographic materials were used for recording X-ray images. Various workers suggested the use of fluorescent screens in contact with the photographic emulsion to reduce the exposure. Swinton and others endeavoured to combine the fluorescent material with the photographic emulsion.[15] A special X-ray paper was introduced in 1896 and was closely followed by the marketing of special X-ray plates, all of which were coated on glass. Supplies of glass from Belgium ceased on that country's invasion in 1914 and films previously used in the early days were reintroduced.[16] The saving in weight and the freedom from breakage obtained by using film, without loss of photographic quality, completely eclipsed the popularity of glass plates which immediately became obsolete. The advantages of plates or films with photographic emulsion on both sides were well known in 1901,[16] but it was not until 1918 that a double-coated film, similar to those in use today, was introduced. Since that time the main advances in X-ray films have been represented by increases of speed, and reduction of grain while retaining high contrast: moreover special varieties of film have been introduced to meet the needs of the many branches of X-ray work. Photography of the fluorescent screen image, as used to-day in mass miniature radiography of the chest and in the cineradiography of the metal flow in casting,[17] was also reported in 1896.[18]

The Renaissance of Industrial Radiography

During the next decade few papers were published on the non-medical uses of X-rays. In 1913 came the first stage in the renaissance when Coolidge introduced his hot-cathode tube which overcame the limitations of the many forms of gas tube. Here was a revolutionary step which, in common with many other outstanding advances in other sciences, was merely an ingenious application of well-known phenomena; in this case, the electronic emission of incandescent bodies so fully investigated by Richardson[19] and others and already applied by Fleming[20] in the thermionic valve.

The increased power of this new tube created difficulties due to the heating of the target. Thermal dissipation was achieved by various means, perhaps the simplest being the use of a thick copper stem, carrying the tungsten target, which conducted the heat to cooling fins outside the tube. Another technique utilising a continuous water supply to the target was presumably an adaptation of the earlier Muller water-cooled gas tube,[21] in which the heat from the target was transferred to water in a reservoir attached to the target. Later Coolidge tubes incorporated oil-cooling which had been utilised in 1896 by both Trowbridge[22] and Edison[23].

Non-Medical Applications of X-Rays

One of the main applications was in the inspection of armament stores and Kaye in "The Practical Applications of X-rays," published in 1922 gave some excellent radiographs of this type due to Pullin who, in 1917, founded the Radiological Research Department at the Royal Arsenal, Woolwich. Another important aspect discussed by Kaye was the inspection of wooden aircraft assemblies for defective workmanship such as concealed overlaps in plywood, hidden splices and splitting of the wood. About this time the value of radiography was realised for the examination of electrical assemblies, arc carbons, aeroplane tyres, insulated cables, golf balls, fireclay pots and, strangely enough, artificial teeth. The X-ray inspection of metals was more fully investigated by 1920. Kaye[24] reported that the maximum penetration of metals was 4 to 5 mm. of lead, 12 mm. of tin, 7.5 cm. of carbon steel, 10 to 15 cm. of aluminium and its alloys and perhaps 30 to 40 cm. of wood.

During the next ten years the interest in this new industrial inspection technique was maintained by many farsighted industrialists, St. John and Isenburger[51] listing some 150 papers published during this period. A major turning point came in 1930 when the United States of America Navy accepted radiographically approved welded boilers.[25] Immediately (1931) the Boiler Code of the American Society of Mechanical Engineers[26] was changed to permit acceptance of X-ray approved fusion-welded pressure vessels. In this country Lloyd's Register of Shipping[27] adopted a similar code for welded Class 1 pressure vessels. With this official backing weld radiography expanded and simultaneously a few foundries both here and in America introduced X-ray inspection for foundry control.

The maintained interest and progress justified the calling of conferences by the American Society for Testing Materials in 1936 and by the Joint Committee on Materials and their Testing in 1938, the latter being held under the auspices of the Institution of Electrical Engineers and attended by lecturers from all parts of the world.

By this time the X-ray tube had developed from the early unprotected glass Coolidge type to a metal-sheathed tube with lead protection to limit the X-ray beam to a well-defined direction, as required by the Recommendations of the British X-ray and Radium Protection Committee first made in 1922 and modified later from time to time. In addition high-voltage cables had been introduced so removing the electrical hazards. The maximum voltage had been increased to 390 kV in 1929 in an experimental continuously evacuated tube.[28] Sealed-off tubes, however, were limited to 300 kV. The Philips 300-kV equipment had an ingenious voltage generating circuit consisting of a double Villard circuit in two units so that each of them could be used separately for operating 150-kV tubes.

The Growth of X-ray Crystallography

Meanwhile in 1912 von Laue had founded a new X-ray science by conceiving the possibility of using crystals to diffract X-rays. The new technique was immediately developed by the classical experiments of W. H. and W. L. Bragg, who by 1915 were able to publish their book "X-rays and Crystal Structure," which contained crystal structures representative of all the basic types. Later, the structure of the silicates was elucidated and about the same time investigations on alloy structures extended the work on the structures of metals. The industrial possibilities became even more obvious with the publication of work such as that of Westgren and Phragmen[29] on the crystal structure of alloys and of iron and steel, of Mark and Weissenberg[30] on the crystalline structure of rolled metal foils, of Polanyi[31] on structural changes in metals due to cold working, of Bradley[32] and his co-workers on alloys, and of the papers by the

Braggs on X-ray diffraction in both pure and applied science.

While new fundamental studies, such as those concerned with equilibrium diagrams, isomorphous replacement, order-disorder transformations and the structure of biological molecules were being undertaken, the application of the technique to industrial problems was widely investigated. 1934 saw the publication of two standard works on X-ray crystal analysis, namely, Clark's "Applied X-rays," and "The Crystalline State" by W. H. and W. L. Bragg, and by 1936 the industrial aspect of the work had reached such importance that the American Society for Testing Materials arranged a symposium of papers on the subject. These, published in 1937, extended over 150 pages and dealt with such widely varying substances as metals, starches, rubber and glasses.

Industrial X-ray Work during World War II

The urgent needs of war created an unprecedented demand for radiography, particularly for foundry control, casting and weld inspection, for development work of many types and, according to Pullin,[33] for investigations on enemy secret weapons. Weld radiography was already well established and the Aeronautical Inspection Department soon defined the scope for radiography in the examination of stressed light-alloy castings.

The very few industrial X-ray installations in Great Britain at this time were quite inadequate to deal with the volume of work. The immediate needs were for X-ray equipment, for photographic materials designed for the work and for trained personnel. With the cessation of supplies of equipment from the Philips works at Eindhoven, on the fall of Holland, our sole outside source was America. Fortunately, by this time the British manufacturers were able to produce all but the high voltage X-ray tubes, which were obtainable from America. Nevertheless, the equipment supply position was poor if not serious. The considerable expansion of radiography justified photographic film manufacturers studying the specific needs of the market, and quite early in the war X-ray films specially designed for industrial purposes became available. Training was a more difficult problem; some operators gained experience by working in established X-ray departments, while others had to obtain what information they could from textbooks and visits to radiographic laboratories. By January, 1943, however, training facilities for industrial radiographers were available in the Kodak School of Industrial and Engineering Radiography.

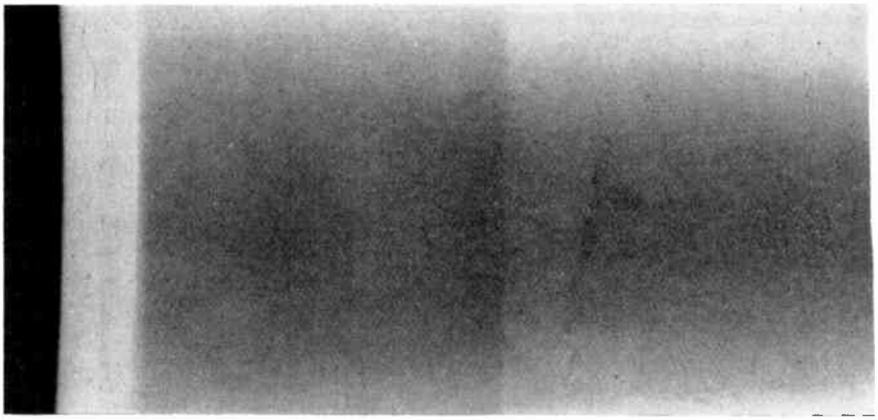


Fig. 2. Radiograph of portion of a porcelain high-tension insulator showing porous region and crack.

By the end of December, 1944, there were some 50 X-ray departments approved by the Aeronautical Inspection Department for the radiographic approval of castings. Some of these laboratories had as many as 20 X-ray equipments. In addition eight firms were approved by Lloyd's Register of Shipping for the X-ray examination of boiler welds. Apart from these, numerous other firms installed X-ray equipment during the war for foundry and welding control and for the examination of products such as electric cables, plastic assemblies, wireless valves and transformer windings. A radiograph, representative of applications in the electrical industry, is shown in Fig. 2, which reveals a porous area and a crack in a porcelain high-tension insulator.

Service needs also called for X-ray equipment, some of which had to be designed specially for specific purposes. Super-voltage X-ray sets, high-speed radiography and the betatron represented the highlights of the many developments in industrial X-ray equipment during the war. The General Electric 1,000 kV set was a logical development of Coolidge's multi-section "cascading" tubes built in 1931 and of Sloan's radiofrequency super-voltage X-ray generator of 1932. The 1,000 kV G.E. tube[34] (illustrated in Fig. 3) utilises a multi-section tube with intermediate accelerating electrodes connected to intermediate tappings on the low-frequency resonance transformer mounted co-axially with the tube. A magnetic focusing coil controls the electron beam so enabling the use of various focal spot sizes. Insulation is provided by freon gas (dichloro-difluoro-methane) at a pressure of about 60 lb. per sq. in. Super high-voltage X-ray equipment using electrostatic generators on the Van der Graaf principle has also been reported.[35]

High-speed radiography demands an extremely intense instantaneous X-ray beam and investigations on these lines had been undertaken by Steenbeck[36] in Germany in 1938, by Kingdon and Tanis[37] in America the same year and in 1940 by Oosterkamp,[38] all of whom used a hot cathode. A remarkable advance was made in 1941 by Slack and Ehrke,[39] who designed a special cold cathode tube capable of carrying loads of 1,000 to 2,000 amperes at 100 kV for about a micro-second. The high voltage applied to the tube is stored in a bank of capacitors and discharged by means of a thyratron circuit actuated by the mechanism being radiographed. The high voltage applied across the tube, shown diagrammatically in Fig. 4, causes an immediate flashover between the cathode *H* and the subsidiary electrode *G*; the high voltage drop across the high resistance *J* results in the transfer of the tube voltage to the cathode and anode *I*.

In Kerst's betatron,[40] developed in 1940, electrons are projected into a doughnut-shaped accelerating chamber placed between the poles of an electromagnet operated by 600-cycle alternating current. As the current applied to the coils increases from zero to its maximum, the magnetic field perpendicular to the path of the electrons increases and accordingly during the short interval the electrons whirl around their path many thousands of times and attain extremely high energy corresponding to 20 million volts in the prototype machine and probably 100 million volts in the one under construction in 1943. When these electrons strike the target, extremely penetrating X-rays are produced. So far there has been no report of any industrial application of these ultra-short X-rays having been produced.

Another recent advance is the use of the Geiger counter[41] as a means of detecting variations in the intensity of an X-ray beam passing through a specimen and thereby investigating its soundness.

The important contribution of gamma-rays to industrial radiography, forecast by the pioneer work of Pilon and Laborde[42] on the Continent in 1927 and by Pullin[43] in Britain in 1933, was fully realised during the war by developments in the preparation, from radium salts in solution, of radon "seeds" which, according to Croxson,[44] have an initial gamma-ray intensity considerably greater than that of the same source of radium. Apart from the greater penetration, compared with that of X-radiation generally available in British works, gamma-ray sources offer considerable advantages owing to their small bulk, which enables them to be used in sites inaccessible to X-ray equipment or where X-rays are not readily available. Rooksby and Jackman,[45] for instance, used gamma-rays for investigations on an electric refrigerator and on a transmitting valve at its operating station.

The considerable growth in the application of radiography to industrial problems has been marked by a great increase in the number of publications on the subject and by the formation of the Industrial Radiology Group of the Institute of Physics in 1941 and the American Industrial Radium and X-ray Society.

Soon after the outbreak of war the wide scope of X-ray crystal analysis, particularly in its industrial aspects, was revealed by a symposium of papers on "X-ray Analysis in Industry," published in the *Journal of Scientific Instruments* in May and July, 1941. Applications to problems in the electrical industry were represented by reports of work on transformer and magnet steels,[46,47] thermionic cathode coatings,[48] filament and heater wires,[49] lead acid accumulators[49] and copper-nickel alloy sheet for cathode-ray tube electrode components.[48] Another important contribution of X-ray diffraction in the electronic industry has been its use in determining the axes of quartz intended for oscillators and resonators.[50] The growing interest in this important branch of X-ray technology led to the calling of the first annual conference on the subject in 1942.

The evolution of industrial radiography has been marked by two periods of feverish activity, both due to wartime requirements to which X-rays have made valuable contributions. X-ray crystallography, on the other hand, has made steadier progress in its shorter life. The success of both these industrial applications of X-rays in numerous spheres during the conflict just ended has amply demonstrated the important contributions which these rays can make in peacetime production.

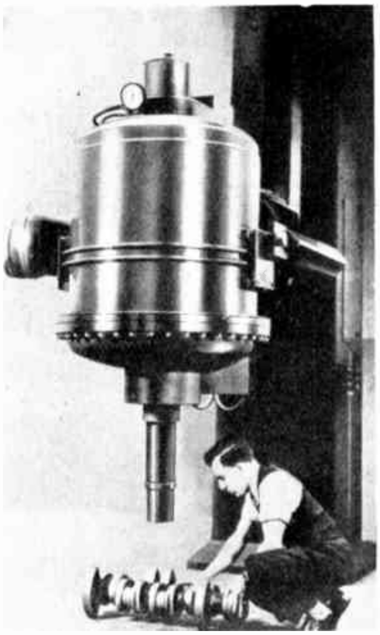


Fig. 3. The General Electric 1,000 kV X-ray tube. *(Courtesy of the Victor X-ray Corporation, Ltd.)*

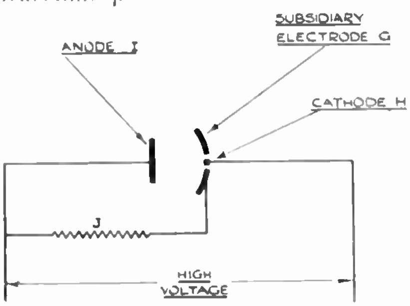


Fig. 4. Diagram illustrating electrode assembly in X-ray tube for high speed radiography.

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Glass-to-Metal Seal Design

Excerpt from a paper on "Glass-to-Metal Seal Design" read by the author before the Institute of Physics in London on June 9, 1945. The full paper will appear in the *Journal of Scientific Instruments*

By W. J. SCOTT, B.Sc.(Eng.), M.I.E.E.*

Introduction

In a good seal the parts not only wet each other, but the stress must be limited to a safe value by proper "annealing or tempering," by suitable balance of expansion, elasticity and plasticity and/or by shaping the seal so that unduly high local stresses are prevented. Annealing or tempering which are necessary for glass by itself are even more so when metal is present. Now if strained glass or metal has zero thickness, it will exert zero stress. If it has next to no thickness the stress and strain in the thicker part will be next to nothing but may be very high in the thinner part. When the glass is thick, and provided the bond is strong the elasticity and/or plasticity of a thin metal wire tube or sheet may be such as to let the metal distort or relax sufficiently to prevent dangerous stress in the glass even when the mismatch is considerable; as with copper to borosilicate glass and molybdenum to silica glass. When the metal is thick and the glass thin compared with the radius of curvature of the junction, the force normal to the junction will be zero. Fracture will then depend upon the elasticity of the glass (plasticity being zero) and on its strength in compression or tension as the case may be.

Relative Thermal Contraction of Glass and Metal

Perhaps the simplest and most accurate way of comparing the relative contraction of sealing materials is to make a flat sandwich seal and measure photo-elastically the strain in the glass, at and parallel to the junction under the thermal conditions for which the result is required. The strain can be estimated reasonably accurately from the seal colour as seen in an ordinary strain viewer by using the Abac of Fig. 1. At the middle of the sandwich, the stress P is given by R/ct, where R is set by the "Strain colour," t is the glass thickness and c is the stress optical constant. For sealing glasses c ranges from 2.5 to 4.0. Values of c for a number of glasses are given in the Abac.

Basic Glass/Metal Constructional Elements

The three basic seal forms are:

(1) Metal facing glass (the "Flat" seal—for zero curvature).
(2) Metal inside glass (the "Rod" seal—for single curvature).
(3) Metal outside glass (the "Window" seal—for single curvature).

With an expansion mismatch the stresses at the junction are as given in Table 1.

Now, solid glass has never been known to fail in pure compression. It fails due to the tension component of stress. Moreover, cracks can only start from a surface (or boundary) either internal or external.

It follows (speaking broadly) that the type "3M" Window seal and the type "1M" Flat seal are safest as they alone have no tension component of stress. "Rod" seals type "2M" and "2G" are both safe enough provided the expansion mismatch is small. If the mismatch is great they will both be unsafe especially if the bond of glass to metal is very weak. When the bond is so strong that on crushing the seal in a vice, the glass cracks off leaving a thin skin of glass adhering to the wire, and the glass shape is also correct; then even quite highly stressed type "2M" Rod seals are safe. Type "3G" Window seals and type "1G" Flat seals are usually unreliable. The more complex seal shapes can be compounded from the three basic types.

Direction of Principal Stresses in the Glass

The lines of principal stress (derived photo-elastically) for four rod seals are shown in Fig. 2. They indicate how high local stress concentration can be caused by sharp corners. The intensity of stress may vary widely along any line. For example, where a tension line is perpendicular to a glass/air surface the tension falls off to zero at the surface.

Stress along the Glass/Air Surface, Nigh and Normal to the Glass/Air/Metal Junction

This stress can be either compression or tension according to the type of seal and the glass angle. Table 2 below shows the type of stress encountered.

TABLE 1

Stress direction relative to junction	Type "M"—metal contracts more than glass: Perpendicular	Type "M": Parallel	Type "G"—glass contracts more than metal: Perpendicular	Type "G": Parallel
1. Flat seal ...	Zero	Compression	Zero	Tension
2. Rod seal... ...	Tension	Compression	Compression	Tension
3. Window seal ...	Compression	Compression	Tension	Tension

TABLE 2

Glass angle (θg)	Type "M"—metal contracts more than glass: Acute (say 10°)	Type "M": Normal 90°	Type "M": Obtuse (say 170°)	Type "G"—glass contracts more than metal: Acute (say 10°)	Type "G": Normal 90°	Type "G": Obtuse (say 170°)
1. Flat seal ...	Compression	Small	Tension	Tension	Small	Compression
2. Rod seal ...	Compression	Tension	Tension	Tension	Compression	Compression
3. Window seal	Compression	Compression	Tension	Tension	Tension	Compression

* B.T.H. Research Laboratory, Rugby.

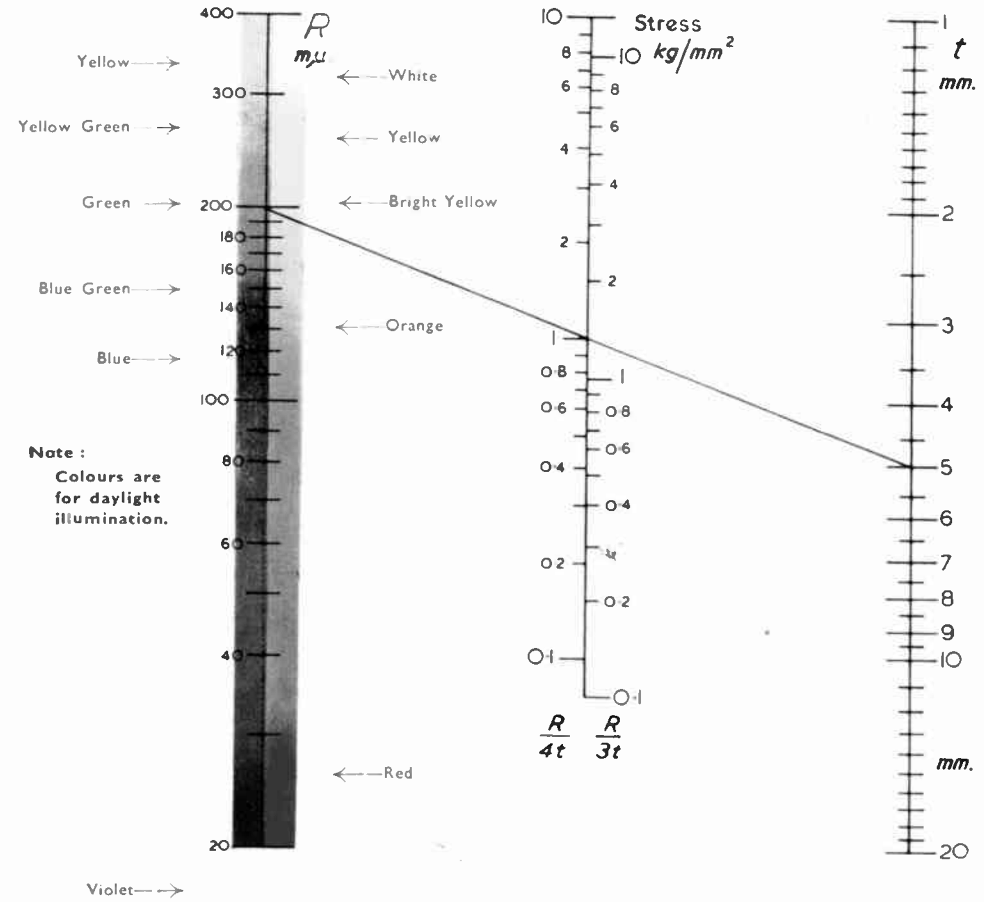

Fig. 1.
Abac for
$P - Q = R\,ct$

Glass	"C" in mμ cm. / Kg cm.
C. 9	4
C.11	3.6
C.12	3
C.19	2 7
C.4)	3 6

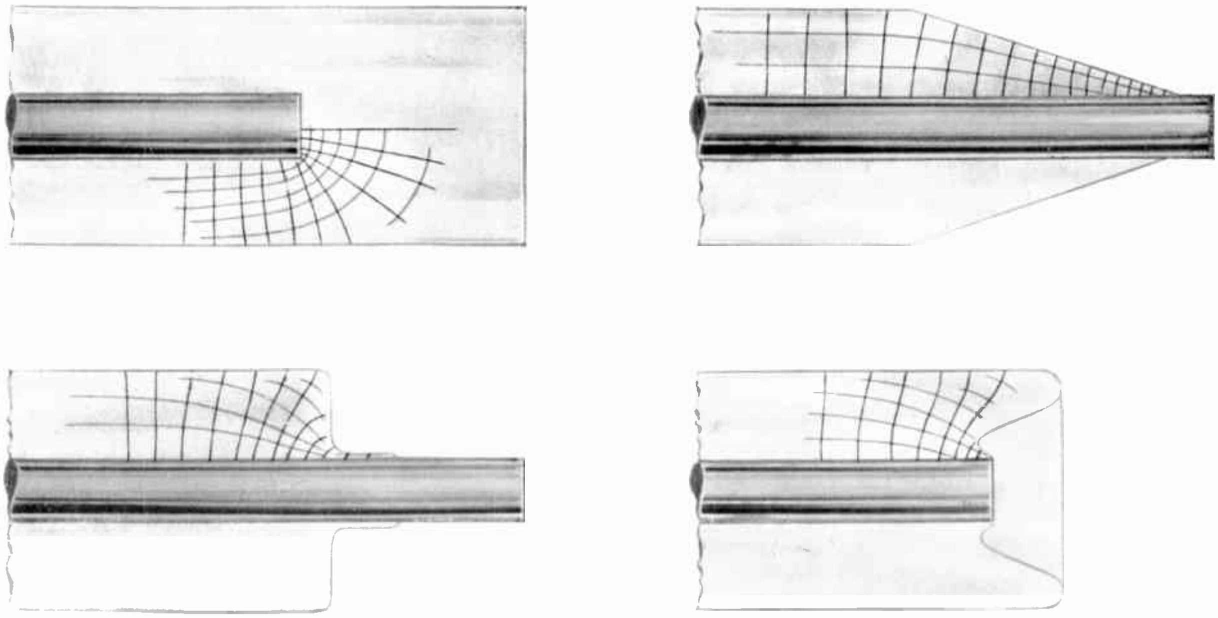

Fig. 2. Lines of principal stress for four "rod" seals.

Type "2M" Rod Seals
Junction in Radial Tension

Type "2G" Rod Seals
Junction in Radial Compression

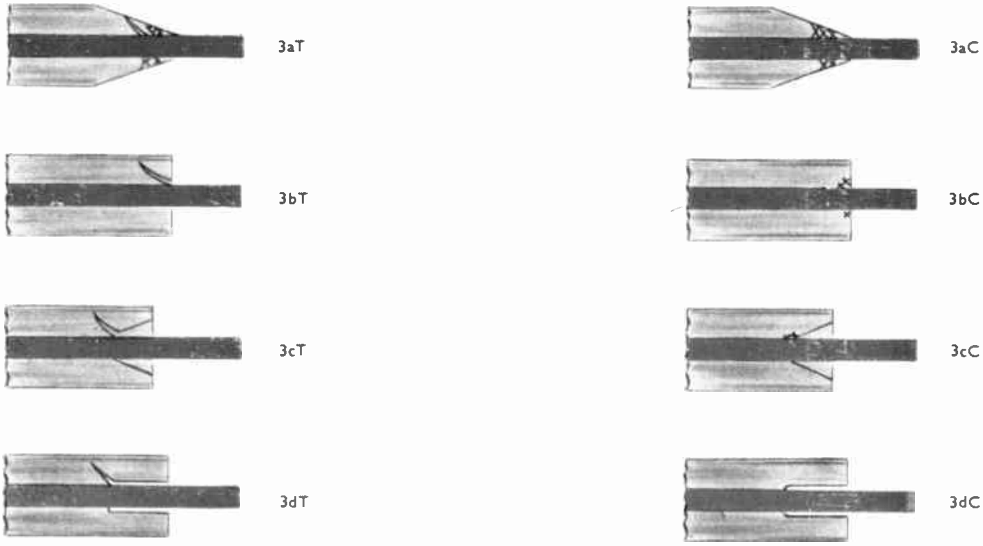

Fig. 3. Crack systems for "rod" seals loaded mechanically so that the free end of the rod is bent downwards.

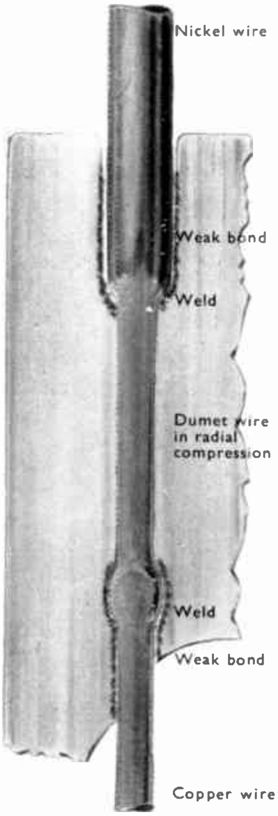

Fig. 6. Rod seal of copper-Dumet-nickel through C.12 glass.

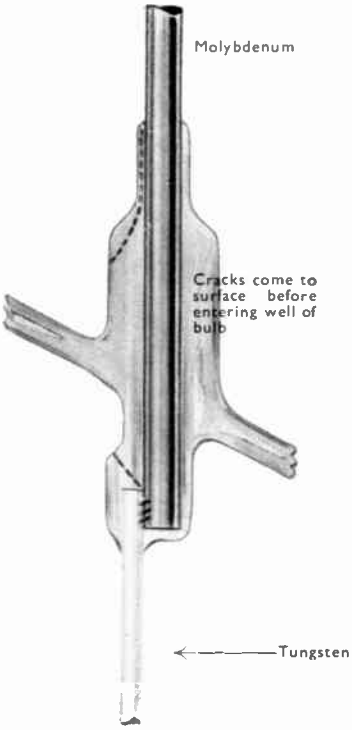

Fig. 4. Rod seal of molybdenum through C.14 glass.

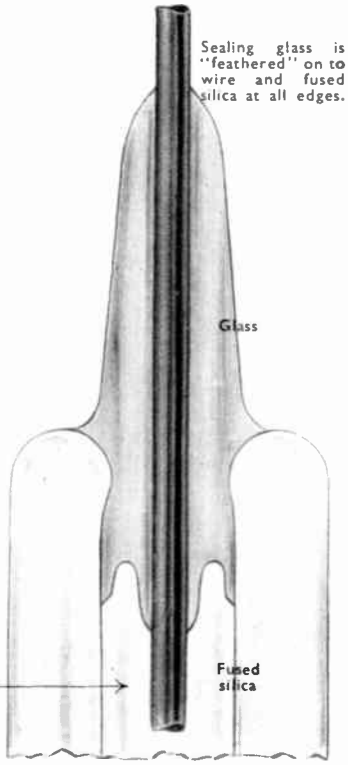

Fig. 5. Rod seal of tungsten into glass into fused silica.

From Tables 1 and 2 and a knowledge of the bond strength, the fitness of sealing materials for a given seal, or the best seal shape for a given pair, can be deduced.

Crack Systems for Rod Seals Loaded Mechanically

In Fig. 3 seals of types "M" and "G" with acute, normal and obtuse glass angles are shown with the rod bent downwards sufficiently to cause fracture at the glass/air/metal junction. In Fig. 31T the weak edge crushes and the radial tension starts a self-propagating crack which, however, comes to the surface because it slopes more than the glass. Because of the different glass shape the self-propagated cracks shown in Fig. 3 (3bT, 3cT, 3dT) do not surface but extend into the body of the glass and if close to the wall of a bulb, they would go right through and cause an air leak.

Where there is only slight radial compression, as in Figs. 3aC, 3bC, the crushed edge does not initiate dangerous cracks. In Fig. 3dC the unsealed glass extension supports the wire and gives it room enough to bend without causing cracks.

Rod Seal of Molybdenum through C.14 Glass (Fig. 4)

This seal is designed for high radial tension between the C.14 and molybdenum whose bonding is one of the strongest known. The seal colour is chocolate brown. The seal ends are shaped in accordance with the recommendations of Table 2 and the glass is symmetrical; the weld is well back from the glass wall so that the crack, which occurs there inevitably, surfaces without piercing the bulb into which the bead is sealed leaving adequate fillets at the joint. The outer portion projects far enough for any crack caused by bending the projecting wire to surface before reaching the bulb. As the operating temperature is increased the radial stress gradually falls until it is zero at about 550° C. Seals of this type have high current carrying capacity.

Rod Seal of Tungsten into Glass into Fused Silica (Fig. 5)

The illustration shows a section of a seal which is used in water-cooled silica glass lamps. The bright seal between the glass and tungsten is very strong. As it is in radial tension the glass angle is made acute to keep the stress within safe limits. The glass into fused silica seal may also be looked on as a type "2M" "Rod" seal with radial tension, so again the glass angle has to be acute. At the normal high operating temperature the stresses will be lower than at room temperature.

Rod Seal of Copper—"Dumet"—Nickel through C.12 Glass (Fig. 6)

A "Dumet" seal widely used in lamps and radio valves is shown in cross-section. These seals are made on carefully controlled automatic machines, which heat the glass and wire correctly. The soft glass is squeezed on to the wire and then heated for some time longer to cause thorough wetting; a borax film protects the Dumet wire from over-oxidation. However, as the copper and nickel wires are not borated, and are indeed left "unclean," the copper wire and its weld are covered with a weak oxide layer which forbids a good tension bond. Hence the copper shrinks away from the glass without cracking it. The nickel is kept cool by a metal die and its weld is covered with a weak oxide layer. The result is that the nickel does not seal strongly to the glass and, like the rod in Fig. 3dC, is strongly supported.

Instruments for Automatic Control

A conference held at the Royal Institution on October 19 by the Institute of Physics jointly with the Chemical Engineering Group of the Society of Chemical Industry

THE Conference on Instruments for the Automatic Controlling and Recording of Chemical and other Processes commenced at 10 a.m. with some general observations on the use of recorders and controllers by A. J. Philpot, O.B.E.

He said: "The first and fundamental requirement for the improvement or modification of any process is the existence of a comprehensive knowledge of the conditions which have accompanied the varying degrees of success attained by the process." He made a plea for the much extended use of recorders in industry as they were of the greatest use in assessing the weakness or merits of a process. One of the greatest bugbears of a Director of Research was to have to investigate the cause of failure in a process which had been trouble-free for years, in the absence of any recorded data.

Mr. Philpot mentioned an interesting memorandum recently issued by the Director of Industrial Training of the State of Victoria, in which it was stated that it would pay a large industrial firm to employ a fully qualified instrument technologist to supervise and install the instrument equipment instead of leaving it to the often empirical knowledge of the operators.

Automatic Control in the Oil Industry was dealt with by D. J. Pull, of the Shell Refining and Marketing Co., who described the requirements for temperature control, pressure control, and special problems in flow and liquid level control. He emphasised that many of the more recent processes would be impossible to carry out without instrumentation of an elaborate type and that the enormous advances made in electronic engineering would be exploited to the full in the instrument industry.

Mr. R. A. Hill, of the Aluminium Plant & Vessel Co., described some aspects of Temperature Control in Milk Pasteurisation and mentioned the difficulties introduced by a long time-lag for heat flow between the control valve and the sensitive bulb of the instrument.

The fundamental characteristics of control systems were discussed fully in a paper by K. A. Hayes, of the Military College of Science, Bury. After classifying the various types of control system in use, the elements of the servo system (power-amplifying automatic reset control) were described and the behaviour of simple and derivative control systems analysed. The subject was amplified in a written communication by Dr. D. G. Prinz on Criteria for Stability in Automatic Control Systems, based on a previous paper on the same subject (*Jour. Sci. Inst.*, *21*, 53, April, 1944).

The papers will be published in full in due course, and copies may be ordered from the Secretary, The Institution of Chemical Engineers, 56 Victoria Street, S.W.1.

The Cambridge Summer School of X-Ray Crystallography

By R. C. EVANS, M.A., Ph.D., A.M.I.E.E.*

EACH September for the past three years a Summer School in X-ray Crystallography has been held jointly in the Department of Mineralogy and Petrology and in the Cavendish Laboratory, Cambridge, under the auspices of the University Board of Extra-mural Studies. The course, comprising a fortnight's intensive instruction in the form of lectures and practical demonstrations, was started as an experiment in 1943 for the benefit of those who practise the industrial applications of X-ray diffraction methods. The very rapid development of the diffraction technique in recent years has compelled many physicists, metallurgists and others to devote themselves to such work without any adequate background of fundamental crystallographic knowledge. In consequence they have not always been able to apply the technique to best advantage, and have often failed to appreciate to the full either its potentialities or its limitations. It was as a contribution towards meeting this difficulty that the Summer School was conceived, and the support which it received each year leaves little doubt that it has succeeded.

It was felt by the organisers, based on considerable teaching experience, that a course of lectures, unless amply supported by practical classes, would be of little value. It was felt, too, that in the short space of a fortnight it would be impossible adequately to cover all aspects of the subject. It was therefore decided that the course should be a highly specialised one, generously illustrated by practical work, and should be reserved exclusively for those themselves actively engaged on X-ray diffraction research. This decision, although undoubtedly correct and confirmed each year, unfortunately involved severely restricting the size of class to accord with the limited resources available for practical teaching, and it was very disappointing each year to have to decline many applications for admission.

In 1943 and 1944 the course consisted of 18 lectures, each followed by a two-hour demonstration class. After a brief introduction to morphological crystallography and to methods of projection, the fundamentals of X-ray diffraction were discussed in terms of the reciprocal lattice, the use of which was illustrated by its detailed application to the interpretation of Laue, oscillation and moving-film single-crystal photographs. The greater part of the course, however, was devoted to a full consideration of the industrially more important powder photograph, and the applications of powder methods to such problems as identification, the determination of phase boundaries in metal systems, the investigation of grain size, the detection of stress, and the study of preferred orientation were discussed at length. In 1945 the scope of the course was somewhat broadened by offering alternative lectures in which single-crystal methods were studied further towards the stage of complete structure determination. This part of the course included discussion of space-groups, structure-factor theory, and parameter determination.

The accompanying table gives an analysis of the attendance year by year, and shows also the total number of applicants. The greatest support came from industrial organisations, rather more than one half of which were metallurgical, but the electrical, rubber, clay, textile, gas, plastic, glass, dyestuffs, diamond and food industries were also among those represented. Experimental establishments of all three of the Services were included among the Government Departments from which members of the School were drawn, and representatives of several research associations attended. University and technical college members came from departments of physics, chemistry, metallurgy and geology.

The success of this series of summer schools prompts certain reflexions of a general nature. Although it was originally started as a wartime measure to meet a particular emergency there is no doubt that such a course is likely to be in demand for some years to come. The industrial applications of X-ray methods are developing with great rapidity, but unfortunately there is no corresponding expansion in the supply of qualified X-ray crystallographers. In the whole of Britain it is in Cambridge alone, in the Department of Mineralogy and Petrology, that an adequate training in the fundamentals of morphological and of X-ray crystallography is available as a substantial constituent of a degree course. Summer schools are of immeasurable value in fostering contacts between workers in a common field, and they have a part to play in bringing to the applied scientist information on current developments of a fundamental nature. It is not, however, their function, nor is it possible, that they should provide a substitute for a course of organised study which should properly extend over a year or more. X-ray crystallography has revolutionised our conception of solid matter, and sooner or later the subject, in its widest sense, must form an essential part of every course in physical science, preferably not as an independent study but as an integral part of physics, chemistry and metallurgy. Until that time comes industry will be starved of properly equipped crystallographers and will be compelled to rely on the necessarily fragmentary training which, at best, a summer school can provide.

TABLE

Year	*1943*	*1944*	*1945*	*1943–45*
Total number of applicants	76	46	81	203
Number accepted from :				
Universities, Technical Colleges, etc.	3	3	9	15
Research Associations, etc.	4	3	5	12
Government Departments	4	4	3	11
Industrial Organisations	19	20	15	54
Elsewhere		1		1
Total number accepted	30	31	32	93

* Department of Mineralogy and Petrology, Cambridge.

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Methods of Applying Negative

THE advantages of negative feedback are too well known to need mentioning here in detail. Very briefly, they are a reduction in all forms of distortion at the expense of a reduction in gain. All forms of distortion and gain are reduced in the ratio $\frac{1}{1 + M\beta}$ in which M is the gain of the amplifier without feedback and β is the fraction of the output voltage which is fed back.

Current Feedback

The chief difference between current and voltage feedback is in their effect on the anode A.C. resistance of the final valve of that section of the amplifier over which feedback is applied. Current feedback increases it: voltage feedback decreases it. Hence voltage feedback should be applied to a valve which is used to deliver power to a loudspeaker or other electro-mechanical device which requires a low R_a (i.e., considerable electrical damping). Current feedback may, however, be used with so-called voltage amplifying valves which are not required to deliver appreciable power and the first three figures opposite are devoted to methods of applying it. The simplest method—illustrated in Fig. 1—consists simply in removing the usual by-pass condenser from the automatic bias resistance R_1. If we regard the valve (almost always a pentode) as a source of constant current of amplitude $g_m E_g$ (g_m = mutual conductance of the valve and E_g = amplitude of input signal to the valve) then the voltage fed back to the grid circuit is clearly equal to $g_m E_g R_1$ so that the fraction by which the gain is reduced is given by

$$\frac{\text{new input}}{\text{original input}} = \frac{E_g}{E_g + g_m E_g R_1} = \frac{1}{1 + g_m R_1}$$

In a typical case where $g_m = 2$ mA/volt and $R_1 = 2{,}000$ ohms, this fraction $= \frac{1}{5}$ so that gain and all forms of distortion are reduced to this fraction of their original value. It is interesting to see by rewriting this expression in the form

$$\frac{1}{1 + g_m R_L \cdot \frac{R_1}{R_L}}$$

which compares directly with $\frac{1}{1 + M\beta}$ that the feedback fraction β is given by $\frac{R_1}{R_L}$. If the removal of the bias condenser gives too much feedback, *i.e.*, reduces the amplification too much, then the value of β can be effectively reduced by short-circuiting part of the bias resistance by the usual bypass condenser as shown in Fig. 2. In this only R_1 is effective in providing negative feedback voltage so that $\beta = \frac{R_1}{R_L}$ again.

Negative Feedback as Volume Control

Sometimes considerable feedback is wanted. Often, for example, variable feedback is used as a means of controlling volume and for this purpose a large feedback voltage is necessary. When the degree of feedback is considerable the amplification of the valve approaches $\frac{1}{\beta}$, *i.e.*, $\frac{R_L}{R_1}$. The circuit of Fig. 3 may be used to give control of volume. The feedback voltage is here developed across $R_1 + R_2$ but only R_1 is effective in providing grid bias. Any desired fraction of the P.D. across $R_1 + R_2$ can be fed back to the grid circuit by use of the potential divider R_3 which hence acts as a volume control. The reactance of C_2 should be small compared with R_3 and that of C_1 should be small compared with R_4 at the lowest frequency in which we are interested. For the sake of clarity all screen feed components and suppressor grid connexions have been omitted from the figures opposite.

Voltage Feedback

Turning now to methods of applying voltage feedback, the most obvious method is that of Fig. 4 in which a potentiometer consisting of R_1 and R_2 in series is connected between anode and cathode of the valve V, the voltage developed across R_2 being fed back to the grid. In this case $\beta = \frac{R_2}{R_1 + R_2}$ provided C_1 is so large that its reactance throughout the frequency range of the amplifier is small compared with R_1. If the amplification of the valve is considerable without feedback, then the gain approaches the value $\frac{R_1 + R_2}{R_2}$ if a large degree of feedback is used. The principle of Fig. 5 is similar save that R_2 here also functions as the automatic bias resistance of V_1 and the feedback is very much more effective than in Fig. 4 since it operates over two stages of amplification. In fact, it is fairly safe to say that the overall amplification of Fig. 5, from the grid of V_1 to the anode of V_2, is given by $\frac{R_1 + R_2}{R_2}$. Fig 6 shows a very simple method of obtaining voltage feedback which requires no additional components. For this case β is equal to the step-down ratio of the output transformer but this method is not recommended owing to the phase changes occurring in the output transformer, which makes accurate calculations of its performance almost impossible. There is often a tendency when feedback voltages are taken from the secondary winding of an output transformer (particularly when the feedback voltage is re-injected several valves earlier in the chain) for the feedback to be positive, with consequent instability, at a supersonic frequency. The last method, illustrated in Fig. 7, is a particularly interesting one. The screen of V_1 is fed from a potentiometer consisting of R_1 and R_2 connected in series and R_1 is connected to the anode of one of a pair of push-pull valves. Thus the screen potential of V_1 is proportional to the instantaneous anode potential of V_3 and so gives negative feedback. R_2 should be very much smaller than R_1. Suitable values are indicated.

Feedback — A Reference Chart

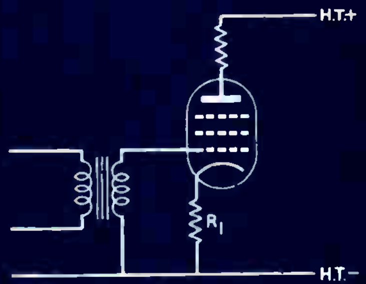


Fig. 1.

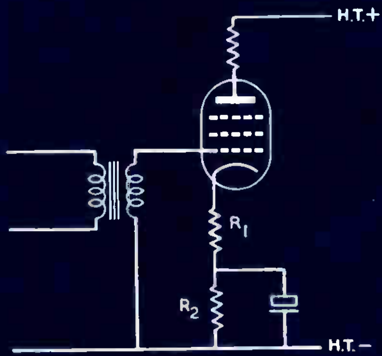


Fig. 2.

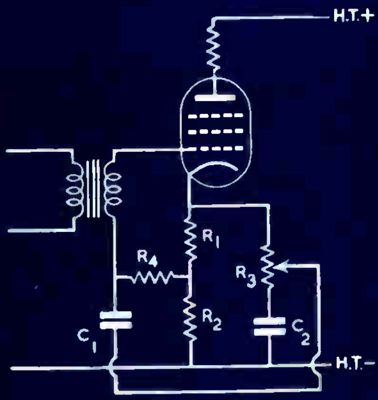


Fig. 3.

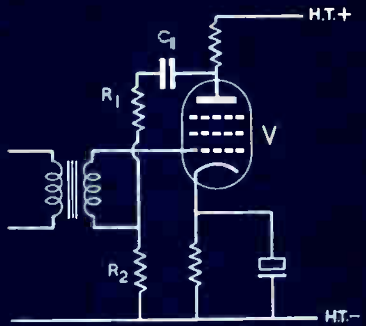


Fig. 4.

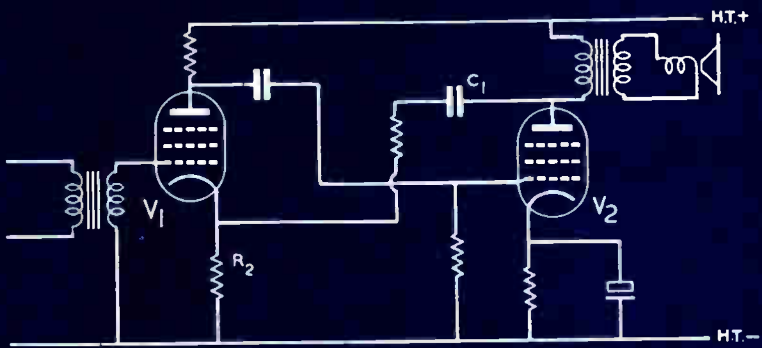


Fig. 5.

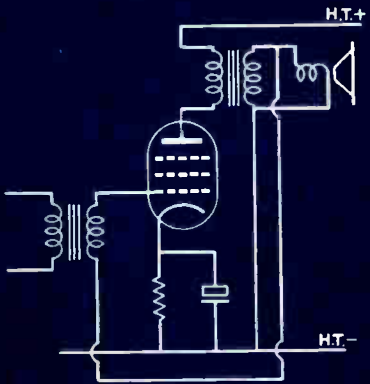


Fig. 6.

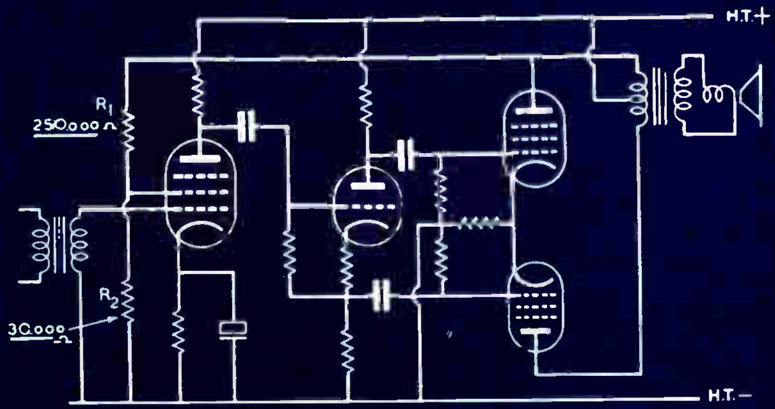


Fig. 7.

A Modern X-Ray Tube Factory

By A. G. LONG*

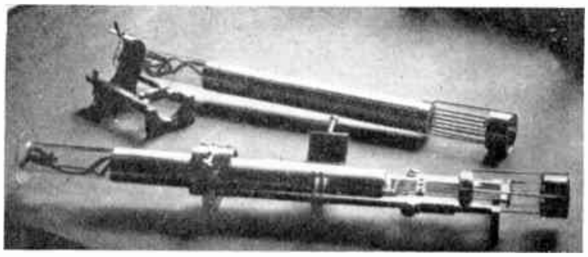


Fig. 2. Assembly jigs for H.T. Rectifier electrodes.

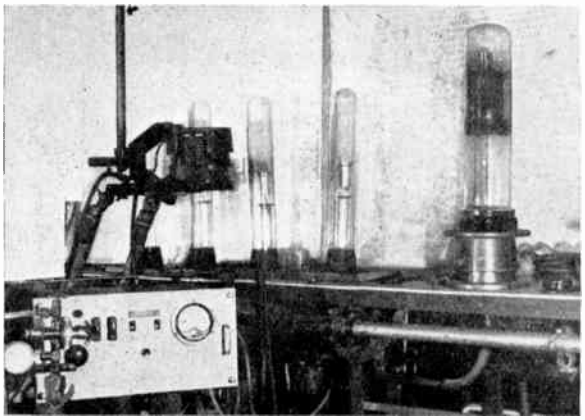


Fig. 6 (right). Equipment for gas treatment of electrodes.

OWING to the variety of manufacturing processes involved, the lay-out of a factory for the production of X-ray tubes and E.H.T. valves presents a problem of some complexity.

Apart from the usual considerations of the progress of work from section to section, there are two outstanding requirements, namely, cleanliness, especially in the electrode assembly and, because of the blowpipes and ovens, special ventilation without draughts in the sections dealing with glass working and exhausting.

Every effort is made to ensure that from the raw material to the completed product handling is reduced to a minimum.

Dealing with the manufacture in order from the raw material to the finished product, it is natural to start at the stores which are divided into two main sections, glass and metal.

In the glass portion storage racks are provided for tubing and bulbs. As a variety of glass types is kept in stock great care has to be taken to ensure that glasses cannot become stored under incorrect headings. Glasses of the same type are also often kept in delivery batches under special headings. In general, glass is also graded in diameter and wall thickness.

The building up of a stock of metals for the construction of high voltage rectifying valves and X-ray tubes demands much care in their selection and they are in most cases spectrographically examined before being received into the stores as usable metals.

Tungsten wire intended for use as filaments receives a further examination in the laboratory, the samples being mounted in a bulb and their temperature measured, by an optical pyrometer, against current density. During these tests, emission currents are also taken as a second check against purity and possible contaminations during processing.

In the testing laboratory is a profile projector giving a magnification of × 10 or × 20, arranged for the examination of filament shapes and their relation to other electrodes.

Other laboratory equipment includes a demountable X-ray tube unit for taking focal spot pictures from sample cathodes. (*See* p. 190, *Electronic Engineering*, October, 1942, also p. 366, *Electronic Engineering*, February, 1943.)

The electrode assembly room shown in Fig. 1 is arranged so as to be entirely self-contained and the interchange of work between this room and the remainder of the factory is kept down to a practical minimum. The assembly of cleaned and degassed electrodes takes place in this room.

The transferring of work between this room and the electrode sealing operations is undertaken in specially designed glass containers, and all operations are carried out with what is almost surgical cleanliness.

* Messrs. Newton & Wright, Ltd.

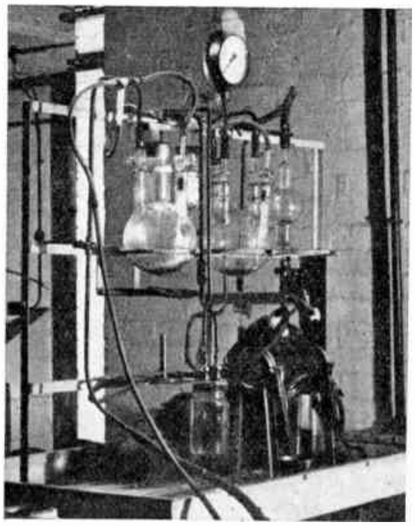


Fig. 3. Oil filling plant for tubes.

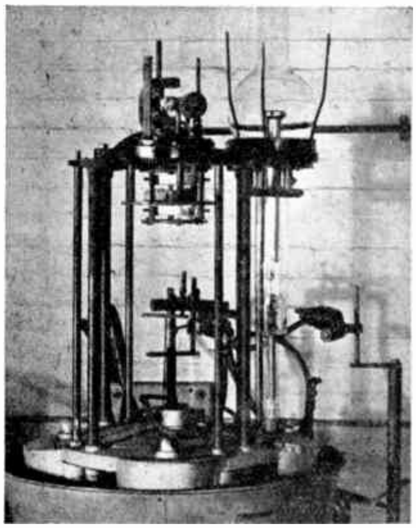


Fig. 7. Four-head drop sealing machine.

The process of physical and chemical gettering is only used in special cases, and therefore reliance has to be placed on processing during construction for the production of a good working vacuum.

In laying out the electrode assembly room, due attention is given to such points as lighting (natural and artificial), heating, and the general comfort of the operators. Electrically heated storage cupboards are fitted at convenient positions for the housing of electrodes not in actual use, but every effort is made to use electrodes as soon as delivered from the degassing benches. When this procedure is not possible the particular electrodes are stored in vacuum containers. Each operator's bench is fitted with a glass top over a white backing: this is easily kept clean and at the same time provides an ideal visual background.

A good deal of jig work is undertaken during the preparation and assembly, and Fig 2 shows an assembly jig for rectifiers together with a pinch assembly made up in it.

Butt and spot welding operations are carried out in the assembly room in order to discourage traffic between this and other departments.

In the general machine shop is undertaken the machining of electrode parts such as X-ray tube targets and cathodes.

The class of work undertaken is of a very accurate nature on both the fitting benches and the machines, the tolerances allowable on most of the work being extremely small. The metals used in the construction of high voltage valves and X-ray tubes call for a special knowledge of their workability. Adjacent to the machine shop is the cable termination department, in which the H.T. shockproof cables are cut to length and terminated in special plugs. Here again great care has to be exercised to keep all work clean, as cables and their terminations have to work at potentials up to 100 kV to earth.

Fig. 3 shows the oil-filling plant for filling the protective enclosures of oil-insulated types of X-ray tubes with specially prepared oil. The actual filling from container to tube body is undertaken under vacuum. The oil is heated in the first glass container as a final precaution against moisture. A small amount is then drawn over to the test pot below and subjected to a breakdown test. If the results of the breakdown test are satisfactory the oil is drawn over

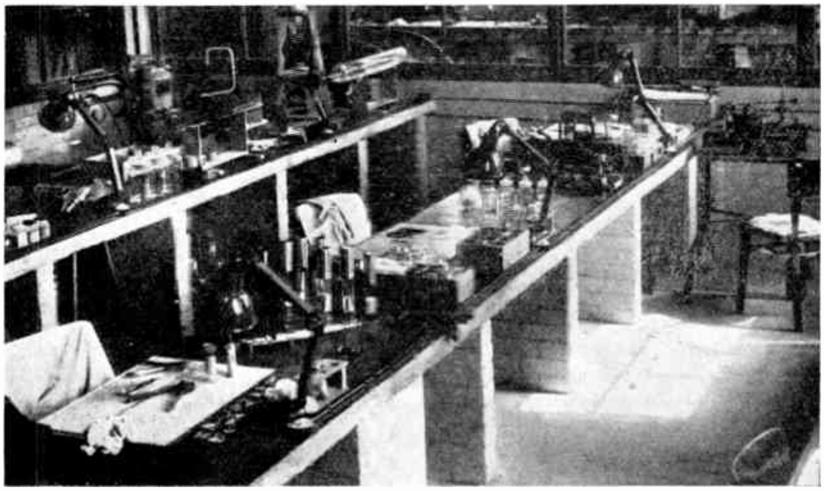


Fig. 1. Electrode assembly room.

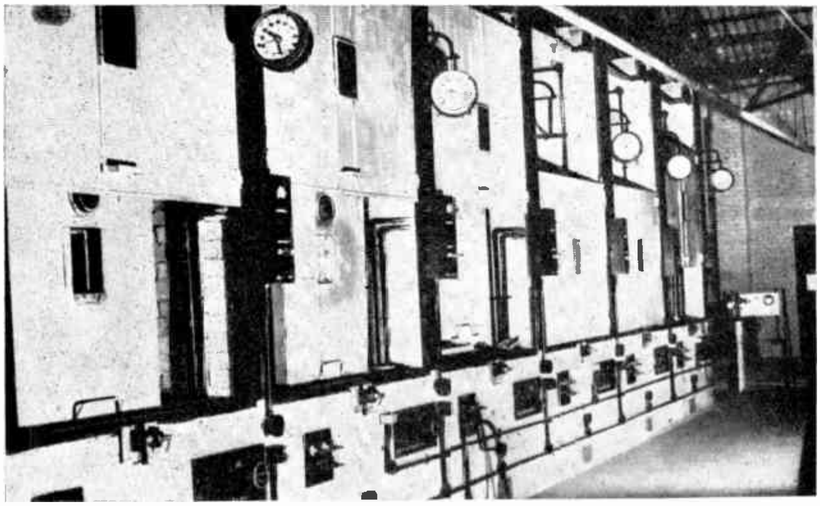


Fig. 5. Exhaust units for tubes operating up to 220 kV.

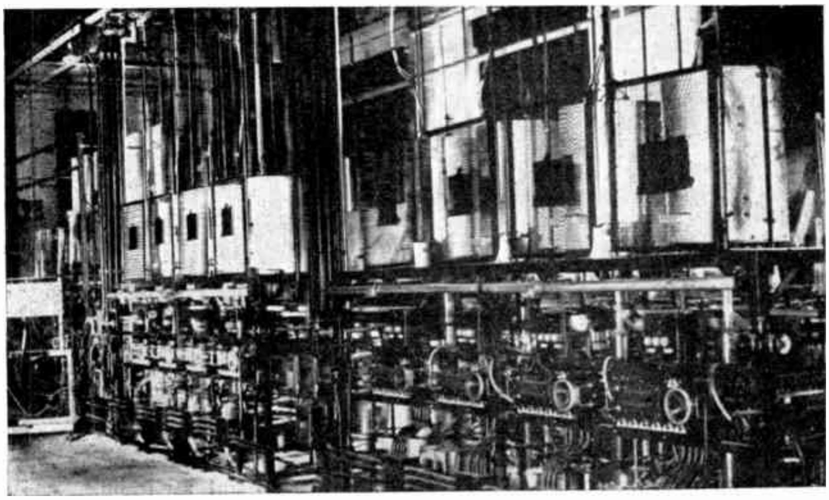


Fig. 4. Exhaust benches for H.T. rectifiers showing baking ovens in place.

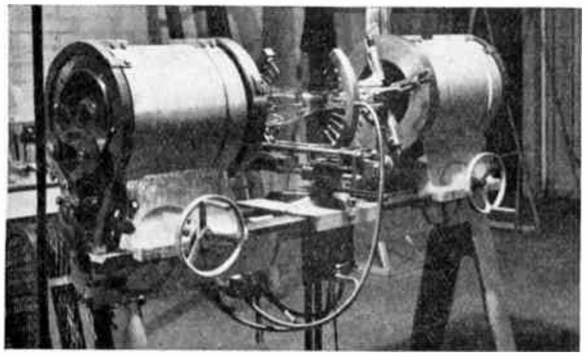


Fig. 9. Large sealing lathe for tubes.

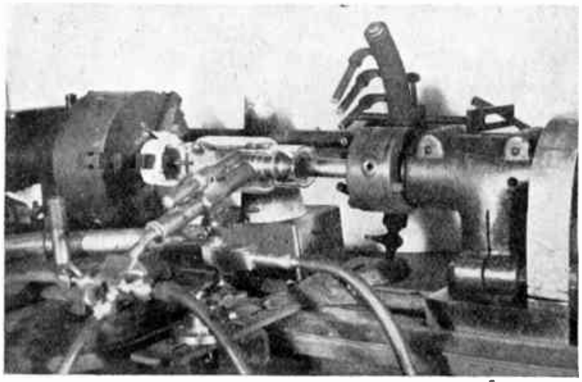


Fig. 8. Small flange-sealing machine.

under vacuum to the second glass container where it is allowed to cool down to a predetermined temperature depending on the room temperature at the time. The expansion accommodation bellows in the protective enclosure is now adjusted to suit the oil temperature and the oil is then drawn over, while still under vacuum, into the enclosure seen on the stand in Fig. 3. The overflow from the tube body is accommodated in the third glass container. The tube body is allowed to stand for a time under these conditions with a 10 in. head of oil on it. If after a final inspection the body is found to be oil tight, it is sealed off from the vacuum system.

Also on the ground floor is the testing department where processing and final tests are made on the valves and tubes. Complete records are kept of all valves and tubes produced, both during production and final tests. These records are filed and referred to whenever a valve or tube is returned by a customer. The report on the returned product completes the life history and provides much useful information as to trend of design.

The soldering and furnace department contains a large hydrogen furnace having a working temperature up to 2,000° C. with a hydrogen-filled cooling chamber attached.

Adjoining the furnace room is the exhausting department in which one of the most important operations in valve and tube construction is undertaken. Figs. 4 and 5 show banks of two different types of exhaust units each designed to perform special tasks. Fig. 4 shows a bank of exhaust benches dealing with 150 kV rectifying valves of small dimensions for use oil-immersed. Each unit is complete, consisting of an electrically heated baking oven, 3 sets of pumps, vacuum gauges and control gear for H.T. bombardment which is interlocked with the gates. Fig. 5 shows the larger type of exhausting unit designed for the processing of valves and tubes with operating voltages up to 220 kV. Here again each unit is complete. The X-ray protection gates necessary on this bank of ovens are interlocked with the H.T. supply voltages. Both the backing and high vacuum conditions are recorded on suitable gauges.

H.F. heating of electrodes is used at all pumping positions and is supplied by valve oscillators mounted in trolleys which are brought up to the positions as required.

An item of interest is the pre-degassing plant. As its name implies, it is used for the pre-degassing of electrodes before they are assembled in the valve or tube. The parts to be degassed are mounted in the vertical glass containers which are then connected to either of the "rough" or high vacuum lines. Special large ground joints are used to form the connexions on to the vacuum system. The parts are then heated by H.F. induced currents derived from an inductance coil which is lowered over the tube. As the gas is ejected from the parts the H.F. currents are controlled to enable the pumps to pass the gas away from the system without flooding the line. Some types of electrode are subjected to gas dosage during heating. The control of these mixed gases is undertaken by the portable equipment seen in the bottom left-hand corner of Fig. 6. This particular equipment is arranged to be portable to allow for its use at any pumping position that requires special attention.

The glassworking department which is on this floor always provides much interest to the visitor. While much hand glass working is still undertaken, the very close tolerances to which valves and tubes have to be made has necessitated the use of mechanical sealing. Fig. 7 shows a four-head drop sealing machine set up for sealing in an anode to a 220 kV valve. The surplus glass of the neck will drop down and away from the flange opposite the cross-fire burners when the seal is made. Another machine of interest is the glass working lathe; Fig. 8 shows a small X-ray tube set up for anode flange sealing in a glass working lathe. The anode and its glass work is held in the right-hand chuck while the tube body is held in the left-hand chuck. Non-oxidising gases are fed into the tube body during the sealing operation. These gases prevent metallic oxide forming on the electrode during the sealing operation, and help in the shape forming of the glass seal; for this latter purpose the gas pressure is increased to a suitable value.

Larger lathes of much the same design are used for the sealing of the larger valves and tubes (Fig. 9).

On the ground floor is the valve capping department. A large number of valves are kept in racks here both before and after capping. Valves stand one week after exhausting and are then tested. After capping and passing through the ageing panels they stand another week. The purpose of these standing periods is to detect fine leaks, cracks or other faults.

The final test on valves and tubes includes measurement of all important sizes in jigs and the making up of a performance curve for each individual valve or tube.

Electronic Applications in Industry

An American Survey

By Dr. W. SOMMER

IN 1944, the Research Department of the McGraw-Hill Publishing Company undertook a survey of the electronic situation in the United States. A very broad cross-section through the American industry was secured by basing the survey on subscribers to the following publications:

American Machinist,
Aviation,
Business Week,
Chemical and Metallurgical Engineering,
Coal Age,
Electrical Contracting,
Electrical World,
Electronics,
Engineering and Mining Journal,
Engineering News Record,
Factory Management and Maintenance,
Food Industries,
Power,
Textile World.

Of nineteen thousand questionnaires mailed only slightly more than 4 per cent. were returned. It is very regrettable indeed that no better response than 796 out of 19,000 was obtained. An inquiry for the purpose of market analysis should be responded to by everybody receiving the questionnaire, irrespective of whether the reply to each and every item is " None " or a figure commanding attention and respect. Some of the works which were within the scope of the inquiry and supplied with a questionnaire had no interest in the statistical result at the moment, yet they might find it highly desirable in a short time hence to base their plans of increasing production on the very same analytical data they, a few months ago, did not support when requested to do so.

A very encouraging fact emerges from the maze of figures which is the backbone of this survey: 796 firms used 16,805 electronic devices, *i.e.*, an average of 21 per firm. Of the 796 replies, 583 came from manufacturers and 213 from non-manufacturers. The metal-working industries top the list with 268 returns, *i.e.*, 45 per cent. of the manufacturing total. Next highest is the chemical industry with 135 replies. Among the non-manufacturers electric utilities are an easy first with 92 questionnaires answered.

For better classification the functions of electronic devices have been divided into eight groups, *viz.*:

Electronic Heating,
Control,
Regulation,
Power Conversion,
Counting (Sorting, Weighing, Inspecting),
Molecular Vibration Uses,
Measurement and Analysis,
Safety.

These groups have been further subdivided and some 120 various groups of applications are listed altogether. In a volume of more than 170 pages statistical data are compiled for the above eight major groups of applications and for eleven separate groups of industry, *viz.*:

Metal Producing,
Metal Working,
Chemical Processing,
Food Processing,
Textile Mills,
Miscellaneous Manufacturing,
Electric Utilities,
Coal Mining,
Metal and Non-Metallic Mining,
Construction (Waterworks, Sewerage),
Miscellaneous Non-Manufacturing.

In Control, Measurement and Analysis, nearly 12,000 electronic devices are used, and yet the firms under survey consider that they have at present 365 problems of control and 240 of measurement and analysis which might be solved by electronic equipment. The 796 firms surveyed account for 1,424 problems solved by 16,805 electronic devices and, at the same time, they suggest another 1,303 problems waiting to be solved in the immediate future, a figure which is increasing daily, if not hourly. Of the 16,805 devices the manufacturers employ 12,685 and the non-manufacturing industries 4,120.

The details so far communicated should be an enormous stimulus to both manufacturers and users of electronic equipment. With the war over, the electronic engineers' inventiveness and the users' desire for automatisation of output and proper production control can now be directed to constructive use and should be given unlimited scope. The report not only reveals the present and possible future position in figures, but also quotes excerpts from suggestions made by many of the surveyed firms. Quite a number of the problems at hand resemble one another either in type or solution. But there also are many interesting suggestions which could not be satisfied with a routine type equipment. One suggestion is that " roll grinding machines could be greatly improved by supplying electronic control on the grinding wheel drive motor to maintain constant peripheral speed on the grinding surface of the wheel under varying feed of work and decreasing wheel diameter due to wear." Another potential application, and not a small one, is outlined by an electrical works: "Use of voltage amplifier and thyratron trigger tube combination to replace electro-mechanical relaying schemes at present used on all power lines. The idea is to standardise the unit and vary applications by variations in input networks and accessories. Thus adapting to operation by voltage, current, frequency, power factor, etc., and assuring faster operation than afforded by conventional type relays, without the necessity of using carrier frequencies."

The following tables give in an abstracted form the essential data of the report.

(a) Number of devices as used at present;
(b) Number of firms using these devices;
(c) Number of firms offering problems for solution.

The number of replies in each category is given in the top row.

A sifting of the potential applications shows that from 796 replies the following classes of applications rank topmost, *viz.*:

Electronic Device for	Contemplated by Firms
Induction heating of ferrous metals ...	52
Electrostatic precipitation	51
Motor speed control	61
Temperature control	65
Rectification... ...	176
Counting	53
	Applications suggested by less than 50 firms are not listed.

Electronic Applications in Industry

Type of Industry and Number of Firms engaged		Heating	Control	Regulation	Power Conversion	Counting	Molecular Vibration	Measurement and Analysis	Safety	Total
Metal producing (33)	(a)	7	1,598	2	19	14	—	89	36	1,765
	(b)	5	24	1	7	5	—	12	9	
	(c)	5	16	7	4	12	1	8	10	
Metal working (268)	(a)	182	2,712	181	1,090	340	—	3,213	772	8,490
	(b)	70	181	20	75	58	—	162	53	
	(c)	80	103	25	19	63	8	67	30	
Chemical processing (135)	(a)	13	522	43	150	65	—	618	151	1,562
	(b)	10	78	14	34	18	—	71	36	
	(c)	29	73	27	8	30	10	53	14	
Food (62)	(a)	—	296	1	13	18	—	43	45	416
	(b)	—	18	1	7	8		18	10	
	(c)	21	29	5	2	26	13	21	7	
Textile (31)	(a)		55	16	2	1	—	15	—	89
	(b)	—	6	7	1	1	—	8	—	
	(c)	8	13	6	5	13	—	5	9	
Miscellaneous manufacturing (54)	(a)	11	103	17	16	12	—	184	20	363
	(b)	8	26	4	9	7	—	22	4	
	(c)	24	19	4	4	14	1	12	6	
Electric utilities (92)	(a)	2	461	119	413	50	—	350	68	1,463
	(b)	2	54	15	30	16	—	46	18	
	(c)	4	62	30	7	11	1	32	13	
Coal mining (27)	(a)	—	16	3	18	3	—	8	3	51
	(b)		6	1	10	2	—	3	2	
	(c)	2	15	4	7	5	1	10	9	
Metal and non-metal mining (29)	(a)	2	34	3	43	10	—	54	104	250
	(b)	2	7	2	8	3	—	10	3	
	(c)	3	18	2	4	9	3	11	6	
Construction, waterworks, etc. (42)	(a)	—	20	5	15	35	—	70	202	347
	(b)	—	7	1	3	14	—	15	6	
	(c)	1	11	2	2	6	3	16	3	
Miscellaneous non-manufact. (23)	(a)	—	144	23	4	305	—	1,335	198	2,009
	(b)	—	7	3	2	5	—	11	8	
	(c)	1	13	4	1	3	—	5	2	
Total manufacturing (583)	(a)	213	5,286	260	1,290	450	—	4,162	1,024	12,685
Total non-manufacturing (213)	(a)	4	675	153	493	403	—	1,817	575	4,120
Grand total (796)	(a)	217	5,961	413	1,783	853	—	5,979	1,599	16,805

The great variety of industries clamouring for solutions of closely related (one is tempted to say one and the same) problems is readily demonstrated by the following instances. These are also of interest because they can be used as a guide to the acquisition engineer or traveller, who might easily overlook an individual firm or a whole group of industries simply because he is not aware of these people struggling with exactly the problem the solution to which he is selling or trying to sell.

Dust, dirt and fume removal problems are experienced by the following groups of industries:

- Antiknock compound,
- Automobile tyres and tubes,
- Butanal, acetane, ethanol, methanol, etc.,
- Cement,
- Cargo bodies and mufflers,
- Coal production and preparation,
- Department stores,
- Electric and gas utility,
- High-voltage capacitors,
- Industrial chemicals,
- Molybdenum,
- Newspaper and job printing,
- Ordnance,
- Petroleum products,
- Radio speakers, vibrators, transformers,
- Sheets, sheeting, pillow cases,
- Tungsten rod, fluorescent powders,
- Telephone service,
- etc.

Door openers and closers are wanted by manufacturers of:

- Bakery products,
- Cotton cloth,
- Electricity,
- Leather and leather soles,
- Macaroni products,
- Printing and foundry types,
- Oil tool equipment,
- Radio and communication equipment,
- Stoves and hot-water heaters,
- Wire rope,
- etc.

Electronic counting devices are needed by:

- Automotive and aeroplane products,
- Biscuits and crackers,
- Brass and copper tubes and wire,
- Cotton fabrics from bale cotton through complete finishing,
- Cement,
- Cold formed sheet and plate products,
- Dairy products, milk,
- Electric wiring devices,
- Electronic heating system controls,
- Electric service,
- Fancy textiles,
- High-power vacuum tubes,
- Leather,
- Margarine, mayonnaise,
- Paper and paper products,

Plywood, lumber,
Pens, pencils, ink,
Pipe wrenches,
Quartz oscillator plates,
Radio components,
Soap and glycerine,
Stoves and hot-water heaters,
Water pumping,
Washing machines,
Wool substitutes,
etc.

A rather important feature is missing in the report, *viz.*, the classifying of electronic devices on a functional basis. Although from the grouping of the equipment according to its applications the operation and function can be deduced, it would have been helpful if tables would have listed the number of photo-electric, magnetic, acoustic, capacitive, inductive, resistive, etc., devices used in control, indication, measurement, and so forth. Many of the applications permit of two or three different solutions, for instance level control (with or without float, capacitive, photo-electric, galvanic contact); door opening (photo-electric, capacitive, weight); temperature control (thermometric, resistive, photo-electric, capacitive); others are more or less unambiguous, for instance carrier control, electrostatic precipitation; illumination control.

On the whole a study of the report is highly commendable. Although its material has been compiled from and for the North American market, and conclusions therefrom cannot be compared with or applied to the English home market without a thorough analysis of the latter, the McGraw-Hill Report clearly outlines the general trend of the electronic industry. This trend is leading upwards for a long time to come.

There remains one wish to be put on record, namely, that a similar and even more extensive analysis of the English electronic market should be produced with no loss of time and its results used in a campaign, first to rouse the interest of the potential user and to supply him with both technical and economical data and expert assistance, then to stimulate production.

It is further suggested to create a body of representatives of all industries concerned with the production of electronic equipment which would act as adviser to the potential user of such devices. This body of representatives has only a consultative function and no commercial activities are attached to it.

New X-Ray Diffraction Apparatus

THE new Philips X-ray diffraction apparatus type 41D has been developed to meet the requirements of both University and industrial laboratories.

A general view of the apparatus is shown in the figure, from which it will be seen that the various components form an integral, self-contained unit. In the base of the cabinet is the high tension generator (including the tube filament transformer)—a circuit consisting of a centre earthed transformer and two oil-immersed rectifying valves being employed.

The control panel, mounted on the front of the cabinet, allows stepless variation of the high tension from 10 to 60 kVp. The filament current is stabilised. In addition the control table incorporates a main switch, overload circuit breaker, press-button H.T. switch, pilot light and an hour meter (10,000 hours and reading to 1/10 hour) for recording exposures and tube life.

The top of the cabinet is formed from an accurately machined iron casting, which provides a flat instrument surface right up to the tube housing. The latter is constructed from a beaded bronze casting accurately machined so that every tube inserted takes up precisely the same position. This means (since the tubes themselves are also accurately constructed) that the necessity for realignment of cameras is eliminated. A rotatable disk carrying the necessary filters is built into each window housing so that the appropriate filter can be immediately brought into position. The main tube support and the window housings are water-cooled to avoid any drift of the X-ray beam due to thermal variations during long exposures.

The X-ray tubes have four windows of Lindemann glass, the thickness of which is kept to a close tolerance, thus ensuring maximum and constant output. The focus, which is located precisely with respect to the tube housing, is 12 × 1.2 mm. so that by taking off at an angle of 6° the effective focus is 1.2 mm.[2] Target materials of W, Mo, Cu, Fe, Co and Cr are available, the maximum continuous ratings being 1,000 watts for W, Mo and Cu, and 600 watts for Fe, Co and Cr.

Precision optical type camera tracks of various lengths, complete with all necessary adjustments and locking devices, can be fixed to the instrument table. These tracks will accommodate the following cameras:

(1) Powder cameras of either 57.3 or 114.59 mm. effective diameter. Provision is made for easily and accurately centring the specimen and for rotating it during exposure. The specimen holder and its motor drive form an integral unit, which is interchangeable with either camera without the necessity of readjustment.

(2) Flat film camera. This can be adapted for recording either "transmission" or "back-reflexion" photographs.

(3) Low angle camera. With this X-ray reflexions at angles to within 5 minutes of the direct beam can be recorded. Slit or pinhole systems 30 cm. long are employed, and the specimen to film distance can be made as much as 60 cm.

(4) Precision "back-reflexion" focusing camera. This is of 10 cm. diameter self-calibrating, and is suitable for gas filling. The specimen can be oscillated by means of a built-in motor.

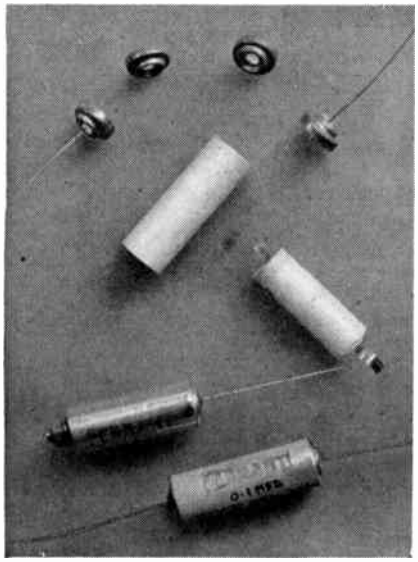
A Weissenberg camera of diameter 57.3 mm. fitted with all necessary movements and attachments, including a goniometer head, is also available.

Four power sockets conveniently located on the cabinet are provided for driving the camera motors and other equipment.

—*Messrs. Philips Lamps Ltd. (X-Ray Dept.), Century House, Shaftesbury Ave., W.C.2.*

Glass-Sealed Capacitors

By V. J. SIMSON*



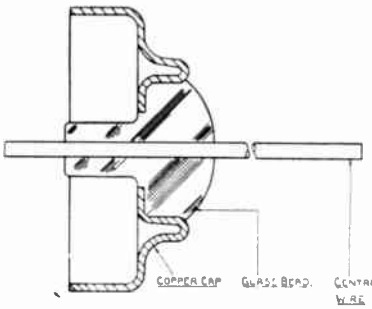


Fig. 1. Sectional drawing of glass-metal seal.

Fig. 2 (left). Component parts of condenser.

Introduction

IN the early stages of the war it became apparent that electronic apparatus for Services' use was being subjected to conditions under which many existing types of components were not suitable. This applied particularly to capacitors of the tubular type which were expected to withstand long sea voyages, unsuitably stored, and exposure to high degrees of humidity and extremes of temperature.

After investigation of the various existing types it was decided to concentrate on a design thought to be superior to any existing one, utilising a technique well proved in the metal thermionic valve—the glass-to-metal seal.

The outstanding advantage of such vacuum-tight seals is the complete absence of organic materials which would be likely to deteriorate, or to contaminate the condenser unit.

The results of life tests at high temperatures with both D.C. and A.C. clearly showed that the existing technique of impregnating with oil or petroleum jelly a rag tissue dielectric capacitor unit produced a unit which would operate for several thousand hours at 100° C.

Construction

A review of the known methods of constructing glass-to-metal seals resulted in the decision to develop a glass-to-copper type in which the difference in the expansion rates of the glass and copper would be accommodated by the special shape of the copper cap.

Fig. 1 shows a section of the glass seal and copper end cap. The central wire is a copper-covered nickel-iron alloy which is matched to the thermal expansion of the glass bead. The thermal expansion of the copper cap is greater than that of the glass bead, but the copper is soft enough to "give" slightly before reaching the breaking stress of the glass. The seal is so designed that the glass bead is under radial compression, with the result that the temperature of the cap may be raised quite suddenly without cracking the glass, thereby facilitating the soldering process involved in fixing the cap to the tubular metal case.

Fig. 2 illustrates component parts of the capacitor unit, which is of tubular shape with a wrapper of high grade chemically neutral paper to give mechanical and electrical protection, and to give rigidity to the unit in the case. The case is of tinned brass with reamered ends to facilitate the entry of the copper caps. Location dimps are used on the tube for the cap, and a vent hole is provided to assist the soldering operation.

No soldered joints are used inside the case because of the risk of contamination by fluxes, and the wire lead passing through the bead is spot welded to the projecting inserted tag of the capacitor unit.

The caps with glass seals are soldered to the case by a process employing low-frequency induction heating. In this, rings of fluxed solder are placed on the cap and run to form the joint when heated. The method of heating gives a uniform rate of heat flow, prevents undue distortion and eliminates cracking of the glass bead. The vent hole allows escape of gases during the heating, and is finally sealed by ordinary soldering iron methods.

Quality and Performance

The sizes of the finished glass-sealed capacitors conform to the standard sizes agreed upon for tropical Service use, and similar voltage ratings have been assigned. For example, the size of a capacitor unit rated at 0.1 mfd. for 350-volt working at 70° C., or 200-volt working at 100° C., is 1.625 in. long and 0.5 in. diameter.

Tropical Tests. — The capacitors constructed as described are hermetically sealed and can be immersed in steam in a closed vessel, maintained at room pressure with a capillary tube, at 100° C. for 100 hours without any deterioration. They can be subjected to continued cycles consisting of boiling and cooling under head of water, and cooling to −40° C., without any deterioration of the unit.

Life.—Life at 100° C. with applied D.C. or A.C. 50 cycles is satisfactory. An example is the life of a capacitor rated at 0.1 mfd. for 350 volts D.C. working at 100° C. With 600 volts D.C. continuously applied the life is in excess of 3,500 hours.

For condensers rated at 350 volts D.C. at 70° C., a life of over 3,000 hours is obtained with voltage of 525V. D.C. continuously applied.

Insulation Resistance.—At 100° C. the insulation resistance is approximately 12 Megohms per reciprocal microfarad, compared with 7,000 Megohms per reciprocal microfarad at 20° C.

Power Factor.—The power factor at 50 cycles is about 0.01 at 100° C., compared with 0.0025 at 20° C.

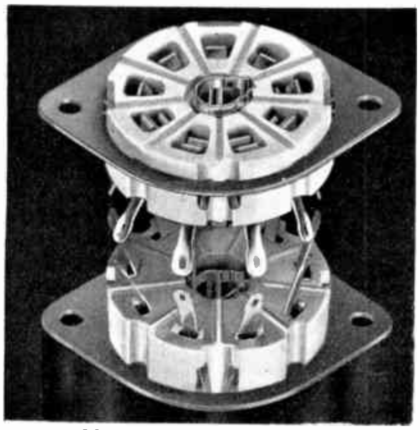
A flattening of the curve of power factor against voltage is noticed after heat treatments without applied voltage.

Acknowledgment

The author wishes to express his appreciation of the assistance rendered by the staff of the Ferranti Electronics Laboratory in this development, and to thank Messrs. Ferranti, Ltd., for permission to publish this note.

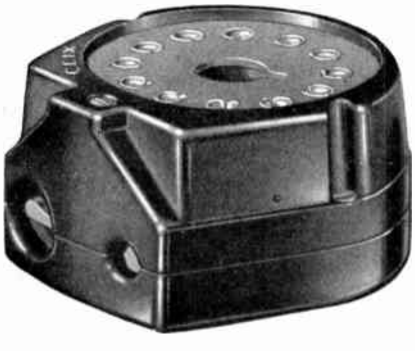
* Ferranti, Ltd., Moston.

NOTES FROM THE INDUSTRY



New Clix Components

Two recent additions to the range of components issued by BRITISH MECHANICAL PRODUCTIONS, LTD., are illustrated on this page. The first is one of the "Clix" cathode-ray tube holders which are available with either 9, 10 or 12 sockets. The 9-pin holder is available with ceramic plate; all are available with high-grade bakelite plate with either standard "Z" turned resilient sockets or with the new open-end rolled type of socket. The second illustration shows one of the "Clix" shrouded cathode-ray tube holders. This component was designed to give protection for all live leads without adding to the complication of wiring. The shroud consists of two moulded plastic sections in which is incorporated a double-entry cable grip. High-grade laminated plates with either 9, 10 or 12 sockets are fitted into the shroud body and may be located in any desired position. Sockets may be either the standard "Z" turned resilient or the new open-end rolled type. The shroud body may be back-board mounted, fitted loose to a rigid cathode-ray tube or used as a wander socket. British Mechanical Productions, Ltd., announce that plug sections for use with this holder will also eventually be included in the range.



German Inventions

The Board of Trade have issued a statement to the effect that H.M. Government have decided that inventions made in Germany since September 3, 1938, shall not be allowed to form the basis of valid applications for the grant of patents, or for registration of designs in the U.K., and such applications will not be accepted by the Comptroller of the Patent Office. Any rights lawfully acquired by non-enemies before September 3, 1939, in inventions for which protection was applied in Germany in the twelve months preceding that date will be safeguarded. Any legislation or other measures necessary to give effect to this decision will be adopted as soon as practicable.

Captain G. J. Redfern

The new chief electronic engineer of BANKS (LONDON), LTD., mechanical and electrical engineers, of 111 Clapham High Street, London, S.W.4, is Captain G. J. Redfern. Captain Redfern was formerly with Mitcham Works, Ltd., and also the Philco Radio and Television Corporation of Great Britain, Ltd.

T.C.C. Capacitors

The list prices of the more popular sizes of their dry electrolytic capacitors have just been announced by the TELEGRAPH CONDENSER CO., LTD., Wales Farm Road, London, W.3. These vary from 2s. 9d. for a 50-mfd. 12 V capacitor to 6s. od. for a 16-mfd. 450 V capacitor. Literature showing the full range of these capacitors, giving ratings, sizes and prices, is in preparation and will be available for distribution shortly.

Mr. A. H. Simons

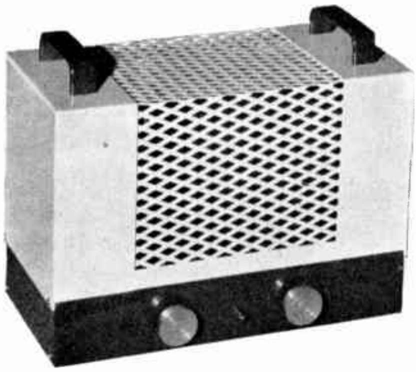
R.T.S. ELECTRONICS, LTD., announce the appointment of Mr. A. H. Simons, late of the Royal Aircraft Establishment, as their chief engineer. This company manufacture radio instruments, components and specialised measuring and recording equipment, with works and offices at King Street, Exeter, Devon.

Marconi New Branch

MARCONI INSTRUMENTS, LTD., have recently opened an office at 30 Albion Street, Hull, for the purpose of providing sales and service facilities in the North of England. The company's representative at this new office is Mr. D. J. Taylor.

Television — A Warning

The Public Relations Committee of the RADIO INDUSTRY COUNCIL have issued a statement welcoming the Government's endorsement of the recommendations of the Hankey Committee on television. They agree that the earliest possible resumption of the television service is obviously a step in the right direction, and maintain that the regular transmission of a still test picture is now urgently needed. The industry stress two points which must be remedied if television is to reach the mass market which has been predicted for it: first, the abolition of the purchase tax, and second, the earliest possible extension of the service to the provinces. Finally, the industry warn present owners of television receivers that these have been standing idle for over six years, and it is most important that they should have an expert inspection before being brought into use again.



Instrument Cases

The Exhibition of Modern Instrument Cases staged recently by A. IMHOF, LIMITED, at their address in New Oxford Street, London, W.C.1, created considerable interest in the trade. The complete process of manufacture as well as the preliminary work of designing the cases was demonstrated, and in addition the first range of post-war models of Imhof's standard cases was on view (the illustration shows a typical example) as well as cases made to fulfil specific purposes. A particular feature of the exhibition was examples of equipment, components and parts made by Imhof's for Radar. Incidentally, we would like to congratulate the company on the attainment of their centenary this year.

NOVEMBER MEETINGS

*NOTE.—In general, visitors are admitted to the meetings of scientific bodies on the invitation of a member, or on application in writing to the Organising Secretary at the address given. In certain cases (marked *) tickets may also be obtained on application to the Editorial offices of this Journal.*

Institution of Electrical Engineers

All meetings of the London Section will be held at The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

Ordinary Meeting

Date: November 15. Time: 5.30 p.m.
The Parsons Memorial Lecture:
"High-Voltage Research at the National Physical Laboratory."
By:
R. Davies, M.Sc.

Radio Section

Date: November 7. Time: 5.30 p.m.
Lecture:
"Radio Measurements in the Decimetre and Centimetre Wavebands."
By:
R. J. Clayton, M.A., J. E. Houldin, Ph.D., B.Eng., H. R. L. Lamont, M.A., Ph.D., and W. E. Willshaw, M.Sc. Tech.

Date: November 21. Time: 5.30 p.m.
Lecture:
"A Method of Increasing the Range of v.h.f. Communication Systems by Multi-Carrier Amplitude Modulation."
By:
J. R. Brinkley.

The Secretary:
The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

London Students' Section

Date: November 28. Time: 7 p.m.
Lecture:
"Production of X-rays and some Electrical Engineering Aspects."
By:
R. A. Briggs.

Hon. Secretary:
R. V. Darton, 27 Church Rise, Forest Hill, London, S.E.23.

Cambridge Radio Group

All meetings of the Cambridge Radio Group will be held in the Cambridgeshire Technical College.

Date: November 20. Time: 6 p.m.
Lecture:
"Frequency Modulation."
By:
K. R. Sturley, Ph.D., B.Sc.

Group Secretary:
D. H. Hughes, c/o Pye Ltd., Radio Works, Cambridge.

Institute of Physics

Electronics Group

Date: November 28. Time: 5.30 p.m.
Held at:
The Royal Institution, 21 Albemarle Street, London, W.1.
Lecture:
"Dielectric Heating."
By:
A. J. Maddock, M.Sc., F.Inst.P.

Group Secretary:
A. J. Maddock, M.Sc., F.Inst.P., Messrs. Standard Telephones and Cables, Ltd., Oakleigh Road, London, N.11.

Scottish Branch

Date: November 15.
Time and place—see local Press.
Lecture:
"Physics in Medical Research."
By:
Dr. A. S. McFarlane.

Hon. Branch Secretary:
Dr. R. S. Silver, F.Inst.P., Research Department, G. & J. Weir, Ltd., Cathcart, Glasgow, S.4.

The Association for Scientific Photography*

Date: November 29. Time: 6.30 p.m.
Held at:
Alliance Hall, Westminster, London, S.W.1.
Lecture:
"Illumination for Photo-Micrography."
By:
A. G. Sabin, A.R.C.Sc., D.I.C., M.Sc.

The Secretary: A.S.P., 34 Twyford Avenue, Fortis Green, London, N.2.

Radio Society of Great Britain

All meetings are held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Date: November 16. Time: 6.30 p.m.
Lecture:
"Aerial Systems for the Radio Amateur."
By:
F. Charman (G6CJ).

The General Secretary, R.S.G.B., New Ruskin House, Little Russell Street, London, W.C.1.

Brit.I.R.E.

London Section

Date: November 21. Time: 6 p.m.
Held at:
The Institution of Structural Engineers, 11 Upper Belgrave Street, London, S.W.1.
Lecture:
"U.H.F. Aerial Technique."
By:
S. G. Button.

Secretary:
G. D. Clifford, 9 Bedford Square, London, W.C.1.

North-Eastern Section

Date: November 14. Time: 6 p.m.
Held at:
The Mining Institute, Neville Hall, Westgate Road, Newcastle-upon-Tyne.
Lecture:
"U.H.F. Aerial Systems."
By:
S. G. Button.

Section Secretary:
H. Armstrong, 69 Osborne Road, Jesmond, Newcastle-on-Tyne.

British Kinematograph Society

Meetings held at the Gaumont British Theatre, Film House, Wardour Street, London, W.1.

Date: November 7. Time: 5.45 p.m.
Symposium:
"Future of Sub-Standard."
By:
Calvin Wright, H. E. Dance, A.M.I.C.E., and R. McVitie Weston, M.A.

Date: November 28. Time: 5.45 p.m.
Presidential Address:
"Recent Technical Developments in Kinematography and Television."
By:
A. G. D. West, M.A., B.Sc.

Theatre Division

Date: November 18. Time: 10.45 a.m.
Lecture:
"Electronics and the Kinema—3. Sound Reproduction."
By:
H. W. Hastings-Hodgkins.

Secretary:
R. H. Cricks, Dean House, Dean Street, W.1.

BOOK REVIEWS

An Introduction to X-Ray Metallography

A. Taylor. (Chapman & Hall, Limited, 1945, 36s. net.) 400 pp., 240 figs.

In the absence of an accepted organ of publication, the extensive literature describing the applications of X-rays in metallurgical research is necessarily widely scattered over many journals and Dr. Taylor has done a valuable service by providing this critical review of what he chooses to call " X-ray Metallography."

The author's long experience of both the academic and the industrial metallurgical applications of X-ray diffraction is indicated by his elimination of those parts of X-ray crystal analysis, *e.g.*, Fourier synthesis, reciprocal lattice theory, which are of little direct value in diffraction studies on metals. A long chapter on " A Study of Thermal Equilibrium Diagrams by X-ray Methods," notable for its introduction to the underlying theory of phase diagrams, justifies serious study before utilising X-ray diffraction in this important branch of metallurgy. X-ray technique is placed in its proper perspective as being complementary to thermal and microscopic methods for establishing equilibrium diagrams.

The other chapters deal with the space lattice, experimental methods of obtaining diffraction patterns, the influence of the atomic pattern on the intensities of the X-ray reflexions, the crystal structures of metals, the measurement of grain-size, grain orientation and the application of X-rays to the study of refractory materials.

The explicit descriptions of the preparation of Debye-Scherrer powder specimens are admirable. Unfortunately this same attention to detail is not seen in references to some other practical aspects, such as the choice and preparation of specimens for back-reflexion work and the alignment of the camera in the X-ray beam. An important point in this respect is the absence of any information on the method of developing the exposed films, a most important feature when intensity measurements are made on them.

The final chapter, entitled " Radiography and Microradiography," does not attain the high standard of the rest of the book and the impression is gained that the author's experience of the subject is somewhat limited. Some of the statements are misleading. On page 313, the speed increase when using tungstate screens is quoted as two, whereas it is always much higher, a factor of 60 being obtained with the slower tungstate screens when radiographing mild steel with 100 kV X-rays. It is odd to find, on page 316, that the prime purpose of thin lead sheet on the walls of the X-ray room is to prevent secondary radiation being scattered back to the film. There is no mention here of the necessity of the lead for personnel protection, but this omission is compensated by the short section on X-ray protection in the Appendix and various references in the text.

The book is pleasingly produced and excellently illustrated (*see* heading). Useful tables appear in the text which is supplemented by an Appendix of over 60 pages devoted to other tables, *e.g.*, K emission spectra and absorption edges, mass absorption coefficients of elements, and to notes on important aspects such as the making of Lindemann glass and cellophane capillary tubes for cylindrical specimens and the indexing of lines in powder photographs by the Hull-Davey method.

Professor Sir Lawrence Bragg has said that a full understanding of the art and craft of X-ray analysis can only be attained by a long apprenticeship. The present book will materially assist in reducing this period of apprenticeship for those engaging in the rapidly extending field of X-ray metallurgy and will provide a valuable survey for those metallurgists who are anxious to keep pace with the progress of this important aspect of metallurgical research.

L. MULLINS.

Electronics To-day and To-morrow

John Mills. (Van Nostrand, N.Y., 1944, ; published by Chapman & Hall, Ltd., 12s. net.) 178 pp., no figs.

Electronics has now reached the popularising stage, and the writer of this book is one of those rare individuals who is able to impart new scientific knowledge in an interesting and assimilable manner. The author's experience in Bell Telephone Laboratories makes the work authoritative and enlivens the historical references, yet every new approach is carefully prepared in a manner which, while explaining all those general points that occur to the beginner, excludes unnecessary material.

The book is divided into three parts, of which the first, " Electrons," introduces the subject and shows the relation between natural effects and what is picturesquely termed " man-made lightning." In the second part, chapters are devoted to electron tubes, including photo-cells as well as vaccum and gas tubes. Part three, " Electronic Devices," covers cathode-ray tubes and television dissectors and a number of special developments which have not been previously popularised. These include the electron microscope and high-speed X-ray (" Electron Optics and Photography "), magnetron, rumbatron and klystron (" U.H.F. Generators ") and the particle-bombarding cyclotron.

The book is brilliantly written and abounds in original and penetrating analogies. As samples may be quoted the interpretation of e.m.f. as " *electron-moving* force " and capacitance as a gap surrounded by two " waiting rooms." The deflection in a cathode-ray tube is compared with a shell falling under gravity and a cross-wind, and the growth of current in a diode or of magnetisation in an iron core is shown to be a common law of nature, *e.g.*, in the reaction of public opinion to a new idea.

Altogether, this book is strongly recommended both to learners and teachers for its breadth of scope and treatment, and for the many new methods of presentation which it contains.

J. C. FINLAY.

CORRESPONDENCE

Circuit Diagrams

SIR,—After reading the article "Circuit Diagrams" on page 546 of your June number, I turned to the description of the bridge stabilised oscillator on page 560 of the same issue.

I was able to follow the description with great ease—owing to the inclusion of small explanatory diagrams—until I started studying the circuit diagram. My reaction to this was: "Puzzle: find the bridge." (*See* Fig. 1.)

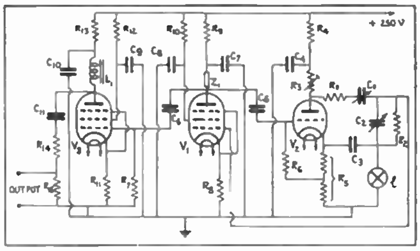


Fig. 1.

I found it necessary to rearrange the drawing (as shown in Fig. 2) in order to understand the working of the circuit.

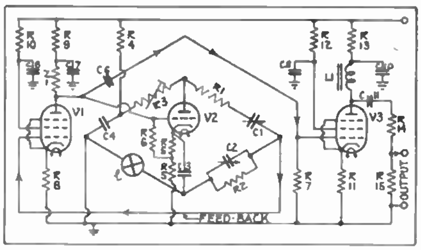


Fig. 2.

I would submit that this figure is clear because the following points *which are mentioned in the first article* have been borne in mind.

1. A common path, dividing into two, is shown as a fork, *e.g.*, the lead from V_1 anode.
2. The main flow from cause to effect is from left to right.
3. Arrows are used to show where this convention is broken.

In addition it is thought that the (unconventional) drawing of a bridge *as a bridge* has made the main feature of the circuit immediately obvious.

D. R. AUGHTSMAN.

H.F. Cooking

DEAR SIR,—Once again it has been stated in a newspaper that cooking by means of radio-frequency power will be one of the treats in store for the housewife in the near future. We consider it is high time the housewife was informed that nothing of the sort is likely. Her visions of placing a joint or a chop in a radio cooker, and of having the same completely cooked in a few seconds, are never likely to come true. Unfortunately, either for trade reasons or for reasons of newspaper publicity, this fact has never been pointed out.

It is quite possible to heat homogeneous media by means of radio-frequency power. For example, bread, cakes, mashed potatoes, minced meat, etc., are suitable subjects for this method of heating, but these do not come under the heading of "cooking" as usually considered.

The joint or chop as mentioned above could certainly be heated up, and at a rapid rate, but the method of heating could hardly be termed "cooking." Fat and lean meat have widely differing loss factors, resulting in widely differing heating in the two cases. Further, if there should be any protuberances or extension on the meat along the lines of the electric field, there will be a concentration of displacement current along it, with consequent overheating and charring, a fact which has been responsible for the destruction of at least one meat pie. These points, although given with reference to meat, apply to any non-homogeneous material.

It is unlikely that a housewife will carefully select the meal to be cooked in such a way that the loss factor is uniform, nor will she care to trim the joint to a uniform shape, merely for the novelty of using a radio cooker. Therefore, might we plead for a little more common sense in statements on the subject of radio cooking?—Yours faithfully,

W. W. WHITTICASE.
P. G. PARISH.
H. BURTON.

ABSTRACTS OF ELECTRONIC LITERATURE

An X-ray Study of the Copper-Manganese Binary Alloy System
(L. D. Ellsworth and F. C. Blake)

The X-ray study reported in this article was made to determine whether super-structures are present in the copper-manganese binary alloy system. It was made in co-operation with the Metallurgical Division of the United States Bureau of Mines in a particular effort to ascertain whether anomalous physical effects measured in certain copper-manganese alloys by the Bureau of Mines could be attributed to the formation of ordered structures in the alloys.

—*Jour. App. Phys.*, June, 1944, p. 507.

Millionth-of-a-Second X-ray Snap-shots
(C. M. Slack, L. F. Ehrke and C. T. Zavales)

The authors discuss the capabilities of a recently developed high-speed X-ray machine which employs a tube using a new type of electron emitter and is supplied with power from a stored energy source. Diagrams are given showing the schematic circuit and wiring circuit of the surge generator and photographs show the generator and X-ray tube. The ways in which the apparatus may be used are illustrated by the description of its applications to the study of ballistics and other subjects where high-speed light photography is not adequate.

—*Westinghouse Engr.*, July, 1945, p. 99.*

A Survey of X-rays in Engineering and Industry
(V. E. Pullin)

A review of the developments of X-radiography in industry and engineering is given. The paper is divided into three sections. In the first, developments up to 1939 are recorded in broad outline. In the second, war-time development, particularly with regard to Service requirements and inspection, is dealt with. The third section is devoted to an attempt to forecast radiographic development in future with reference to the inspection of welds and castings and X-ray apparatus and equipment.

—*Jour. I.E.E. (Pt. I)*, June, 1945, p. 226.*

Geiger Counter Spectrometer for Industrial Research
(H. Friedman)

X-ray diffraction has many applications in industry but its techniques have been confined until recently mainly to the laboratory with its highly trained personnel, as conventional procedure entails photographic exposure, processing and density comparisons of the finished film strips. The new spectrometer described in this article measures X-ray intensities and diffraction angles directly, without intermediate photographic steps, by using a Geiger counter tube to actuate a scale-of-64 flip-flop circuit that feeds an impulse register.

—*Electronics*, April, 1945, p. 132.

Electronic Control of X-ray Exposure Time

To provide extreme uniformity between films for maximum analytical value, an electronic device for controlling the time of X-ray exposures has been developed and is described in this article. The X-rays pass through an object and then strike a fluorescent screen where they are made visible. A section of this screen is scanned by a phototube which actuates an electronic amplifier and relay which opens the X-ray circuit when sufficient light for proper exposure of the film has been produced.

—*Electronics*, Jan., 1945, p. 146.

X-ray Inspection with Photo-electric Tubes
(H. M. Smith)

The X-ray absorption method of detecting defects in materials makes use of a familiar technique. The usual practice has been to determine differences in absorption by means of a photographic film. In some applications the photographic method is impracticable because it requires a comparatively prolonged exposure and the costs of film and labour would be too high. This paper describes a method in which a phototube, viewing a fluoroscopic screen, replaces the film process. It was developed for the inspection of a large number of fuses in a very short time, but other applications are indicated.

—*G.E. Rev.*, March, 1945, p. 13.*

X-ray High Tension Plant with Resonance Transformer
(S. H. Jenson)

A description is given of the equipment of the new X-ray laboratory at Copenhagen. A resonance transformer which constitutes a Tesla coil, the secondary winding being wound round the X-ray tube, is employed. The apparatus is contained in a pressure vessel designed for 5 atmospheres internal pressure. At atmospheric pressure flashover takes place at 350 kV, but at 4 atmospheres pressure 850 kV can be carried with safety. Graphs are given showing the voltage distribution on the secondary coil and the resonance curve of the transformer. When operating the plant at 800 kV with a current of 1.5 mA the total power required amounts to 6.5 kW, 2.7 kW of which are consumed by the motor-generator set.

—*Engr. Digest*, June, 1945, p. 154.*

Industrial Radiography
(W. T. Sproull)

The author reviews the characteristics of X-rays, with reference to their generation, absorption, and tube voltage and current, and describes how X-rays may be used effectively for inspection of welds, castings and finished products. The effect of focal spot size and target-to-film distance on the quality of a radiograph is discussed and a table gives general rules to obtain improved contrast and definition and points to observe when taking a radiograph of thin objects. Types of radiography mentioned include micro-radiography and semi-automatic radiography used in the production line inspection of small articles.

—*Electronics*, June, 1945, p. 122.*

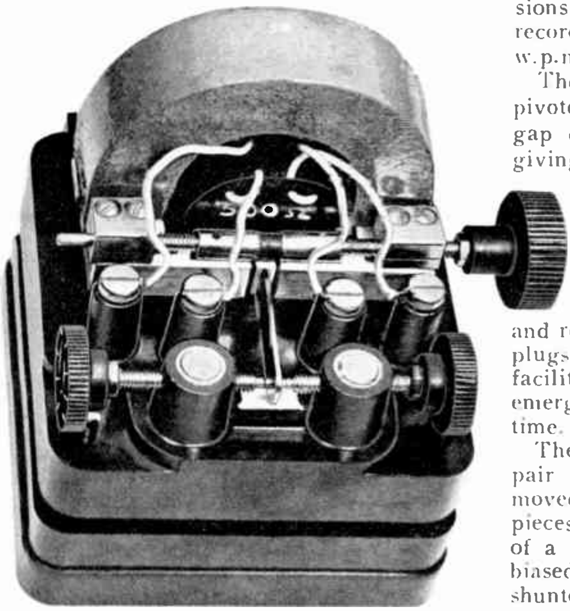
Geiger Counters
(J. D. Craggs)

Radio-active elements emit radiation of three main types, alpha-, beta- and gamma-rays, and it is essential to be able to distinguish between these different radiations. Several methods are available for studying these and other ionising particles, one of which makes use of the Geiger counter. The operation of counters is considered in detail, and their application, to the measurement of X-rays and ultra-violet radiation, the determination of the diffraction pattern of materials, the detection of flaws in large metallic specimens, chemical analysis, etc., is discussed.

—*M-V. Gaz.*, Oct., 1944, p. 342.*

* Abstracts supplied by the courtesy of Metropolitan Vickers Electrical Co. Ltd., Trafford Park, Manchester

A High Speed Telegraph Relay



A HIGH speed relay developed by the Automatic Telegraph and Radio Transceiver Co., Ltd., combines small overall dimensions with a high sensitivity and a recorded working speed of 1,000 w.p.m.

The armature of the instrument is pivoted in the centre of the rear pole gap of a Ticonal magnet assembly, giving a long armature-tongue assembly in the space available and allowing maximum winding space for the coils.

The whole relay is assembled on a moulded baseplate, and connexion is made to the coils and relay contacts by means of spring plugs moulded in the base. This facilitates changing the relay in emergency with a minimum loss of time.

The relay is biased by means of a pair of mild steel sleeves which are moved in front of the magnet pole pieces by a threaded rod. Rotation of a knob causes the armature to be biased in the direction of the unshunted pole piece.

Adjustable contact screws are mounted on bakelite pillars which are integral with the baseplate moulding. The platinum contacts will carry a maximum current of 0.3 A.

The relay can also be provided with an interference suppression unit (Type 301S/1944), into which it plugs to form a complete shielded unit.

The unit does not provide for spark suppression at the relay contacts, this facility being normally included in the local circuit. With suitable spark suppression, the contacts of relay Type 301 are tested with a load of 0.5 amperes.

Specification :

Sensitivity	2.5 mA at 300 w.p.m.
Inductance	0.4 H. (500 coil).
Contact pressure	35 gm. for 0.003-in. gap with zero current
Transit time	0.5 m/sec. with 0.002-in. gap at 300 w.p.m.
Dimensions (without suppressor)	3¼ in. by 2¾ in. by 2¾ in.

Further details can be obtained from the A. T. & R. T. Co., at 329 High Holborn, W.1.