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TELEGRAMS
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Revelation

THE technical Press, or this section of it at any rate, viewed the world-shaking or epoch-making events of the past month with mixed feelings. On top of the atomic bomb, which was sufficient to provide scientific material for discussion for several weeks, came the full release of information on Radar* to the extent of 30,000 words of official notes—sufficient for a complete issue of ELECTRONIC ENGINEERING.

This release conveniently took place on the day before VJ-day so that the Press could have two quiet days in which to assimilate the mass of material and present suitable portions to the public.

Unfortunately the Paper Controller did not see fit to grant extra paper to the technical Press so that they could deal adequately with the subject, so the brief account which appears in this issue must be taken as an earnest of more to come.

A special tribute must be paid to the staff of T.R.E. who staged a first-class demonstration at the Ministry of Information, manned by people who really knew what they were talking about It is greatly to be regretted that this was not developed into a Radar Exhibition and opened to the public, but possibly this idea has already been considered and everyone will have a chance of seeing the most amazing scientific demonstration of the past ten years.

Some form of demonstration is necessary, as it is almost impossible to obtain an adequate idea of the enormous combined effort of the research staffs and manufacturers without seeing the gear at work.

How inadequate mere words are to convey a picture was shown by the B.B.C. broadcast on the " Story of Radar." Although the presentation held the interest for over an hour, the technical man must have wondered exactly what impression of the actual " works " the public received. What a pity that television was not available at the time, and how well the story could have been told on the cathode-ray tube itself !

(By the way, the B.B.C. conception of a technical conference where each weighty decision is followed by a burst of elfin music on the strings and harp is novel and well worthy of adoption by all works conferences.)

If certain sections of radiolocation are now rendered obsolete by the atomic rocket, or whatever new device is brewing, it is a slight consolation to think for the moment of the peace-time applications and the opportunities they will afford to the ex-Radar operators and Radio profession.

The Ministry of Civil Aviation have already pointed out that the aeroplane of the future will employ radiolocation as a matter of course for navigation, identification, landing, and flying in fog.

If current research is successful it will also be possible to detect and map areas of bad weather more accurately than before.

Existing forms of apparatus can be adapted to other means of transport—it has even been suggested that the blind may carry " Radar-aids " like a deaf-aid, but one would imagine that the interpretation of signals received when crossing Piccadilly would require more intensive training than that of an R.A.F. operator.

We are looking forward to publishing more information on this subject from time to time, and in the meantime add our quota of thanks and congratulation to those who have made this war-winning marvel possible.

* In common with many others in this country, we prefer Radiolocation, but it is sometimes more convenient to use the shorter term.

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CONTENTS

The History of Atomic Disintegration

By N. FEATHER, Ph.D., F.R.S.*

RECENT events have demonstrated in an unmistakable manner the enormous energy which may in certain circumstances be obtained from a chain of atomic disintegrations brought about through the action of neutrons on uranium. It is the object of this article to trace the history of the subject of atomic disintegration over the past fifty years—for it is precisely within that period that the subject has developed from its beginnings to its present state of world-importance.

But first let us be clear on the question of energy liberation. When we say that there is a store of available energy in a lump of coal we are using colloquial language to express the fact that the chemical combination of carbon and oxygen is an exothermic process; that energy is released in the form of heat when these elements combine. It is meaningless to say that this energy is resident in the lump of coal considered by itself. On the other hand, when we speak of the available energy of a mass of high explosive (always a chemical compound or a mixture of such compounds) we are speaking of the heat energy which may be released in a chemical transformation taking place in the explosive material itself. Some "triggering" process is necessary, but, when this has been provided, the reaction is propagated throughout the whole mass of material, and the final products of the explosive transformation are again chemical compounds, but possessing less available energy than before. In the atomic (nuclear) domain we shall see that a similar division may be made: the only sense in which we can speak of there being energy available in an intra-atomic (nuclear) form in the ordinary stable atoms of which most of the world is constituted is in relation to their interaction with other atom nuclei in exothermic transformations—on the other hand, there are various types of "unstable" atoms the nuclei of which emit energy spontaneously. With these nuclei, in each individual case, the transformation may truthfully be described as an elementary explosion (not needing external "triggering")—and the nuclear products which result obviously possess less available energy than they did when combined in the complex nucleus which suffered the explosion. Nevertheless, at this stage, there is nothing suggesting a self-propagating process involving a chain of separate nuclei; nothing in the nature of an explosion on a macroscopic scale. To produce this—or, in fact, to obtain energy usefully from nuclear processes of any kind—we have, as we shall see, to make use of transformations involving the interaction of nuclei of one type with those of another. Transformations of this latter type we may speak of as induced transformations—in contra-distinction to the spontaneous transformations of the unstable nuclei which have already been referred to.

Natural Radioactivity

As a matter of historical fact, it was the spontaneous transformations which were discovered first. The phenomena of radioactivity, observed for the first time—almost accidentally—by Becquerel[1] in 1896, were recognised by Rutherford and Soddy[2] in 1902-3 as evidence for a type of disintegration of the atoms of uranium and thorium which was quite uninfluenced by any physical agency which could be brought to bear. Considering an individual atom of uranium, this disintegration, when it occurred, was shown to consist in the expulsion of an α-particle with considerable energy of motion. The heavy atom which was left behind naturally was different in properties from the original atom of uranium, since the α-particle was suspected at the time—and later was proved—to be a charged atom of helium in its own right. The residual heavy atom was also found to be radioactive, and a whole sequence of successive disintegrations was traced out showing that in general an invariable succession of disintegrations was followed, involving the spontaneous emission of eight α-particles and six β-particles (negative electrons) in all, before the original unstable uranium atom became stable as an atom of ordinary lead. It will be noted that this description is a cautious one on two points: we have spoken of the disintegration of the uranium atom "when it occurred"—and we have spoken throughout of atoms, rather than of the nuclei of atoms. We shall elaborate these two points in turn.

The proviso "when it occurred" is necessary because the radioactive properties of uranium are such that, for any individual atom, disintegration may occur soon or late—and the average time that an observer would require to wait to witness the disintegration of a specified atom is about 6,600 million years. Only because the number of atoms in a weighable amount of matter is so immense does the radioactivity of a lump of uranium appear to gross observation as a steady and continuous process of emission of particles and energy. But all radioactive substances—all descendants of uranium and thorium—are not so long-lived. The atoms of some of them are characterised by average lifetimes of minutes or seconds—or fractions of a microsecond. Obviously, it was with the shorter-lived products that the crucial experiments in the investigation of the subject were done. Rutherford and Soddy showed that for each such product, considered in isolation, the phenomenon of emission of particles proceeded according to a universal law. That this law was of the

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same form as that for a monomolecular chemical reaction was the compelling evidence which pointed inescapably to the conclusion that the changes were spontaneous: that single atoms acting by themselves were disintegrating on the basis of the "laws of chance." The form of the law of decay of activity was the same for every short-lived product examined, only the "constant" in the expression of the law was different from one product to another. This constant, λ, the reciprocal of the average lifetime of the atoms of the substance concerned, is, more significantly, the probability (reckoned per unit time) that any given atom of the substance will disintegrate. The law of decay is the exponential law represented by:

$$N = N_0 e^{-\lambda t}$$

(N = number of atoms still unchanged at a time t after N_0 atoms of the substance have been brought together in the sample under examination)—and Rutherford and Soddy were confident, on the basis of their experiments with the shorter-lived products, that the same law, only with a very much smaller disintegration constant λ, must apply to the apparently constant radioactivity of uranium (as also to that of thorium) as well. In this extrapolation from direct observation the objection that the long-lived radioactive bodies contravene the law of conservation of energy is adequately met: the supply of energy is not inexhaustible—it becomes effectively exhausted when in the end all the atoms of uranium (or thorium) have finally changed into lead. And, we may add, energy is available at all only because a heavy atom is a highly complex system: it already possesses less energy than its fundamental constituent particles would do in the free state, but it so happens that some heavy atoms (uranium and thorium) also possess the possibility of readjusting their constitution by the expulsion of particles, and thus passing over to configurations of lower energy content still. That is the phenomenon of radioactivity.

The Nuclear Atom

The second point was that we have spoken, up to date, of atoms rather than of atom nuclei. This is a reflexion of the historical fact that the constitution of the atom was not worked out until some years after the phenomena of radioactivity had been fairly completely investigated and "explained." That was natural, because, until this had been done, the means were not available for the experimental attack on the problems involved. But the α-particles from radioactive substances were soon recognised as ready-made projectiles for just such an attack, and in 1911 Rutherford[3] put forward the nuclear hypothesis to explain the anomalous results (concerning large-angle scattering of the particles in their passage through matter) which had been obtained by Geiger and Marsden in his laboratory at Manchester some two years previously. This hypothesis was universally accepted almost from the start, and Bohr, in particular, made it the basis of further important theoretical advances. As a result of Moseley's experiments on characteristic X-radiation it became the basis, also, for the physicist's interpretation of the Periodic Table of Mendeléeff, and for the assignment of atomic numbers—from 1 (hydrogen) to 92 (uranium)—as representing the numbers of unit positive charges carried by the nuclei of the atoms in question. The masses of individual atoms were determined later (Aston[4] 1919, following the pioneer work of J. J. Thomson)—all but about 1 part in 4,000 of the mass of an atom belongs to its nucleus—and then it was found that integral numbers were again in evidence; to quite a high order of accuracy a unit could be chosen in terms of which the masses of the nuclei were integral—from 1 (hydrogen) to 238 (uranium) in terms of this unit. But a given element might be constituted of atoms of different mass (isotopes), thus chlorine (atomic number 17) with mass numbers 35 and 37, and, to take an extreme case, tin (atomic number 50) with mass numbers 112, 114, 115, 116, 117, 118, 119, 120, 122, and 124. Others were "simple" elements, so far as could be discovered (thus fluorine, atomic number 9, mass number 19). The notion of isotopy was not, in fact, new: it had been put forward at an earlier stage by Soddy, on the basis of radiochemical evidence (1913), at the time when it became clear that radioactive phenomena were to be explained in terms of the spontaneous disintegration of nuclei in particular, rather than of atoms in general. This was an important clarification, and what we have said about available energy and highly complex systems must, in view of it, be referred to the atom nuclei as such. Had it been otherwise it would have been entirely surprising: the energy liberated in radioactive disintegration is in general so great that it would be difficult to think of its liberation in the reorganisation of quasi-stable complex systems which were not already highly "condensed." Nuclear matter which, according to present views, has a density of the order of 10^{14} g./cm.^{2}, has, however, the requisite degree of condensation, and difficulties of that type do not arise.

Artificial Disintegration

The use of α-particles as projectiles for nuclear bombardment was responsible for the next great step forward in the history of our subject. Here we shall mention two stages in the advance, though the interim was filled in with important experiments consolidating the first stage. Rutherford's experiments, during the years 1917-19[5] convinced him that it was possible to bring about the disintegration of ordinarily stable nuclei in favourable cases of close collision between the fast-moving particle and the nucleus on which it impinged. He obtained direct evidence for the liberation of protons (hydrogen nuclei) from the nuclei of nitrogen atoms which had suffered collision in this way. Later experiments showed that the α-particles were captured in the process, nuclei of oxygen (charge 8, mass 17 units) being formed as a result. Then in 1932 Chadwick[6] showed that similar collisions between α-particles and beryllium nuclei resulted in the ejection of neutrons. The neutron, of mass unity with no charge, had for some time been regarded as a possible constituent of heavier nuclei: these experiments showed that the expectation was well founded. In fact, it is now assumed that all nuclei are made up of protons and neutrons only, the charge number (atomic number) giving the number of protons in a nucleus and the difference between the mass and charge numbers the number of neutrons. The particles, at the close distances involved, attract one another with strong forces, and the system as a whole has lost energy by comparison with that composed of the same particles widely dispersed. If a heavy radioactive nucleus emits an α-particle, it in fact emits a complex particle consisting of two protons and two neutrons in a very intimate state of association; if it emits a β-particle (negative electron), it does so at the expense of one of its constituent neutrons, which thereafter has all the properties of a proton in the residual nucleus.

New Methods

From 1932 onwards the subject of atomic or nuclear disintegration developed at an ever-increasing rate. Disintegration induced by α-particle bombardment had by that time been effected for almost all nuclei of mass number less than 40, and when it was found that bombardment by neutrons also produced disintegrations (Feather, 1932)[7] it was soon established that neutron bombardment was almost equally effective for the heaviest elements as for the lightest (Fermi, 1934)[8]. The reason here is not far to seek: positively charged particles, such as α-particles, suffer repulsion when they approach a nucleus, the more intense the higher the nuclear charge; neutrons, on the other hand, suffer no such repulsion and can enter into the structure of even the heaviest nuclei without opposition. Then the subject was advanced by the development of "artificial" means of producing intense beams of high-energy particles—protons, deuterons (nuclei of hydrogen of mass number 2), and helium nuclei ("artificial" α-particles) speeded up from the relatively low velocities which they possess when produced in the ordinary discharge tube or low-voltage arc. The high-voltage generator of Cockcroft and Walton,[9] the cyclotron of Lawrence[10] and the electrostatic generator of van de Graaff[11] should certainly be mentioned—and to these should be added the induction accelerator (Betatron) of Kerst,[12] a later development for the production of high-energy electrons. With all these particles, with the neutrons obtained through their use as primary projectiles, and with X-rays of high energy, a multitude of cases of nuclear disintegration has been brought to light and investigated. These disintegrations have resulted not only in the transformation of stable species into other stable species of nuclei (following the capture and emission of particles), but also in the production of some hundreds of previously unknown radioactive species of short lifetime. These are the so-called "artificially radioactive" bodies, the first of which was discovered by Curie and Joliot in 1934[13]. To digress on their significance in relation to the physicist's views on the stability of nuclei in general, or on the practical uses to which they have been put in biological research or medical treatment would obviously be outside the scope of this article. We need only make two remarks concerning the disintegration results as a whole. First, that the yield of disintegrations is, in most practical cases, very small indeed—from one disintegration in a thousand, in a very favourable case, to one in a million bombarding particles, in more usual circumstances—and, secondly, that the individual process of induced transformation is just as likely to be endothermic as exothermic, that is it is just as likely that energy will be lost as that it will be gained, on balance, in the disintegration, when in fact it occurs. If this were the last word on the utilisation of intra-nuclear energy, clearly the whole matter would be a closed story; that it is not so is due to the discovery in 1939 of a further type of induced disintegration—the last in our history—the fission of heavy nuclei.

Fission

Already in 1937 difficulties were beginning to pile up in respect of the interpretation of the results of experiments on the transformations produced by neutrons in uranium and thorium. Certain difficulties were noted by Meitner, Hahn and Strassmann in May of that year, others were remarked on by Curie and Savitch in October—and even throughout the following year continued experiments by Hahn and Strassmann produced little in the way of a satisfactory elucidation. Then in January, 1939, the German workers[14] were able to report the unambiguous radiochemical proof of a startling fact: active isotopes of barium and lanthanum were among the many artificially radioactive bodies produced in these transformations. Meitner and Frisch[15] discussed this discovery on the basis of the Bohr theory of heavy nuclei. They concluded that a true case of nuclear fission was probably involved (the uranium nucleus being supposed to divide into two roughly equal fragments after capturing a neutron), and they showed that the process which they postulated might well result in the liberation of a very large amount of energy. The highly energetic fission fragments which were thus predicted were detected by Frisch in a direct experiment, and Joliot established the fact that a complicated mixture of active elements was obtained when these fragments were collected on expulsion from a layer of neutron-irradiated uranium. Very quickly the study of the new phenomenon engaged the attention of workers in most of the main physical laboratories throughout the world. For our purposes there is only one further remark to be made, but it will be realised that it is all-important. It was found by Halban, Joliot and Kowarski[16]—and the conclusion was rapidly substantiated by other workers—that in this most highly exothermic of all nuclear reactions there are also produced, at the instant of fission, further neutrons capable under suitable circumstances of causing more fissions in other uranium nuclei. The conditions for a divergent chain reaction were thus shown to be realisable—and an atomic bomb, or a device for the controlled liberation of nuclear energy, became a sober possibility within the realm of achievement.

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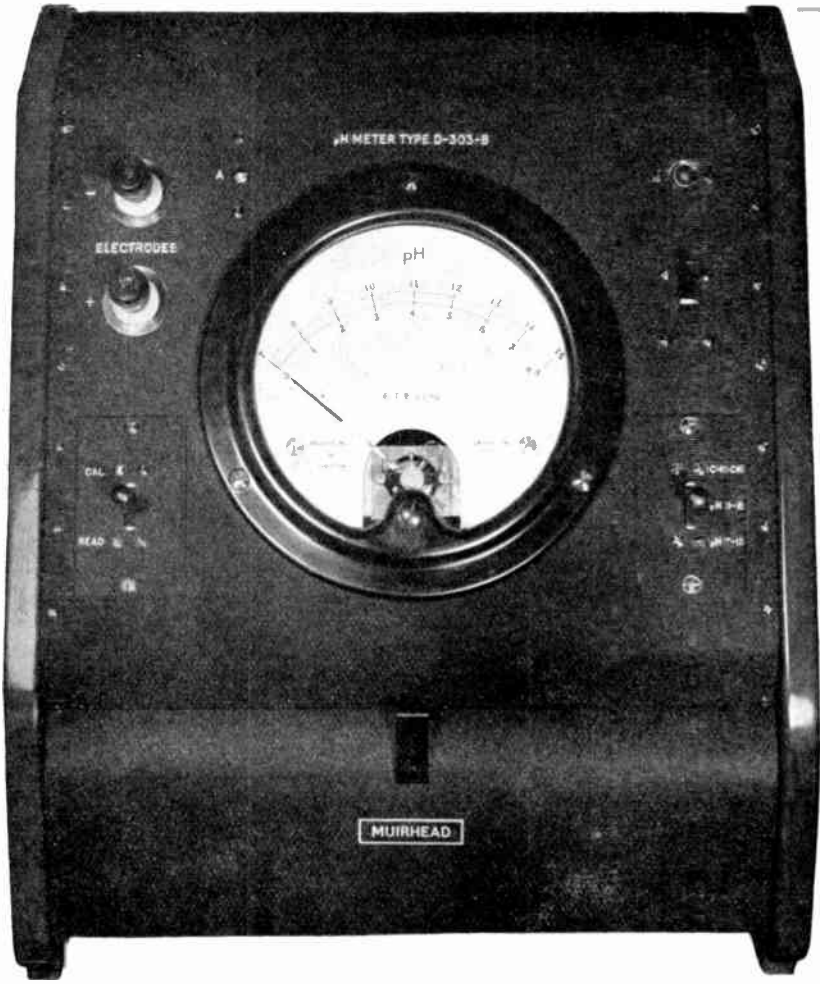

General view of *pH* meter.

A Direct-Reading *pH* Meter

A New Principle for the Design of Direct-Reading Valve Voltmeters for the Measurement of pH *with Glass Electrode Systems*

(Pat. Appl. No. 17293/44)

By R. H. THORP, B.Sc.*

THE design of valve voltmeters to measure the potential of high resistance systems has engaged the attention of a large number of workers for many years and as a result several instruments of varying degrees of complexity have been evolved. Such apparatus has been in increasing demand of recent years owing to the introduction of glass electrode systems to measure *pH*.

In order that the problem shall be fully appreciated it is necessary to consider some of the fundamental characteristics of glass electrode systems. It is not intended, however, to deal with the physico-chemical aspects of *pH* theory for which a text book such as that by Britton[1] should be consulted.

The glass electrode system can be best considered by reference to Fig. 1. This is a highly diagrammatic sketch of the general principle of such a system. The electrode may vary widely in physical form and a reliable type is the spiral glass electrode of which one form has been described by MacInnes and Belcher[2] and a similar type designed by Pope, in use in these laboratories, is shown in Fig. 2.

In this type of apparatus a thin-walled spiral of glass tubing (generally Corning 015) is used. This glass has a low electrical resistance and gives a *pH*/E.M.F. change in agreement with the Nernst equation. It is filled with the solution of which the *pH* is to be measured. The spiral is surrounded by a jacket filled with a solution of an electrolyte of known *pH* and containing a standard half-cell which is either the mercury/calomel or silver/silver chloride type. Connexion is made to the fluid in the spiral by means of a reservoir containing a similar half-cell in a solution of a 3.5 M or saturated potassium chloride. This latter solution is prevented from mixing with the test solution by means of a sintered glass plug or other partial obstruction.

In Fig. 1 the contents of the spiral glass tube are represented in the right-hand compartment with the half-cell immersed directly in the solution of unknown *pH*. The glass membrane separates the reference solution in which the second half-cell is immersed, represented by the left-hand half of the sketch.

We can consider the two half-cells, which are arranged so that the potentials produced by each are in opposition, to give E.M.F.s of E_{e1} and E_{e2} respectively. If both half-cells were in solutions of the same *pH* value and of equivalent chlorine ion concentration these E.M.F.s would be equal and cancel out. In practice the chlorine ion concentration is arranged to be equivalent in each side so that the differences in the resultant potential of the system are caused by differences in the *pH* of the electrolytes surrounding each cell.

The basic difference in potential measurable across the two half-cells is of the order of 58 millivolts per unit of *pH* and is slightly influenced by ambient temperature. It can be calculated from the formula $E = 0.19837 \times T$ where E is the potential developed and T is the temperature in degrees absolute

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(273 + t° C.), and some values derived from this formula are given in the table below, from which it will be seen that for each degree Centigrade change in temperature the potential changes by 0.2 millivolt or by approximately 0.33 per cent. of the value at 20° C.

Values of E.M.F. in Millivolts per *pH* Unit at Different Temperatures

t° C.	MV	t° C.	MV	t° C.	MV
6	55.3	15	57.1	24	58.9
7	55.5	16	57.3	25	59.1
8	55.7	17	57.5	26	59.3
9	55.9	18	57.7	27	59.5
10	56.1	19	57.9	30	60.1
11	56.3	20	58.1	35	61.1
12	56.5	21	58.3	38	61.7
13	56.7	22	58.5	39	61.9
14	56.9	23	58.7	40	62.1

This is an important fact and governs the degree of accuracy and temperature correction required in associated measuring instruments, and will be referred to later.

In addition to the potential due to differences of *pH* on each side of the glass membrane there may be small but constant differences in the E.M.F.s of the two half-cells, especially as they are commonly dissimilar, a silver/silver chloride and a mercury/calomel electrode being used together in commercial designs (Marconi, Cambridge and other makes). There is also a small potential due to the strain in the Corning glass tube which we may call E_{as}, the "asymmetry potential." This is constant for periods of hours but may vary from day to day.

When the resultant potential of the entire cell is measured the value obtained is the algebraic sum of all the E.M.F.s enumerated above, and when the constants are subtracted the difference is linearly proportional to the *pH* difference of the two solutions.

Since a glass membrane separates the two half-cells the internal resistance of the entire electrode is high and may be of any value between 15 and 200 megohms according to the design. Special designs of glass electrodes having very low resistances of the order of $10^4 - 10^5$ ohms have been described by Mouquin and Garman,[3] but they are rather too fragile for routine use.

The dip type of electrode, which consists of a sealed bulb of Corning glass enclosing a silver/silver chloride half-cell and used in conjunction with a calomel half-cell contained in a straight tube, the two being dipped into the liquid of unknown *pH*, has a much higher resistance than the spiral-tube type.

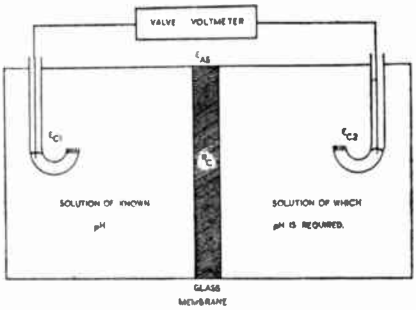

Fig. 1. Diagram illustrating the principle of operation of the glass electrode for the measurement of *pH*.

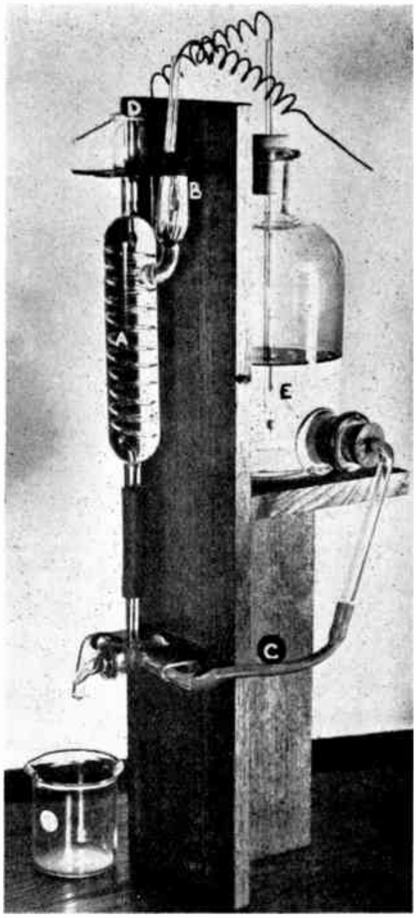

Fig. 2. Spiral glass electrode. A is the spiral of Corning glass surrounded by 2.5 M KCl in N HCl and connecting with the side-arm B containing a calomel half-cell. E is a reservoir containing 3.5 M KCl and a second calomel half-cell. It is connected to the contents of the Corning spiral by means of the rubber tube C containing a glass bead to prevent free flow of the solution when the T tap is turned. The cup D is the inlet for the solution to be measured, and which after use is drained out into the beaker by operating the tap.

It is essential that the entire Corning glass area of any electrode shall be totally immersed in the two electrolytes or else variable results may be obtained according to the depth of immersion. This is easy with the spiral type as the junctions between the spiral tube and jacket are well inside the jacket itself and this is completely filled with solution. The modern dip electrodes are similarly made of Corning glass fused to ordinary glass tubing immediately above the bulb itself.

It is the high internal resistance of the glass electrode which has created problems of measurement since the electrode can give virtually no current to operate a meter.

It was soon obvious that an electrometer valve coupled to a sensitive galvanometer could be used to measure these potentials, and this was done by such workers as Harrison[4] and Morton.[5]

Since electrometer valves are expensive and have a very low efficiency Dubois[6] and DeEds[7] successfully replaced them by ordinary radio valves run under reduced conditions of anode voltage and cathode emission. Since, however, under these conditions the valves were very inefficient either a sensitive galvanometer was still required or additional stages of D.C. amplification were added. One of the first workers in this field was Pope[8] who designed a direct-reading instrument of this type in 1927 for use with the quinhydrone electrode, as the glass electrode was not then in general use; and it is noteworthy that negative feedback was incorporated to give increased stability.

Most of these instruments were battery operated because cascade D.C. amplifiers employ floating batteries between the stages to correct the positive voltage which would be imposed on the following grid by the previous anode, and it is virtually impossible to achieve a similar result by mains operation. A recent instrument of this type was designed by Penther, Rolfson and Lykken[9] which was direct reading although most types employed a potentiometer and used the electrometer as a null-point detector. In some cases, such as the instrument designed by Chun-yu Lin,[10] a condenser has been used to block the grid current of the first valve so that the instrument is then

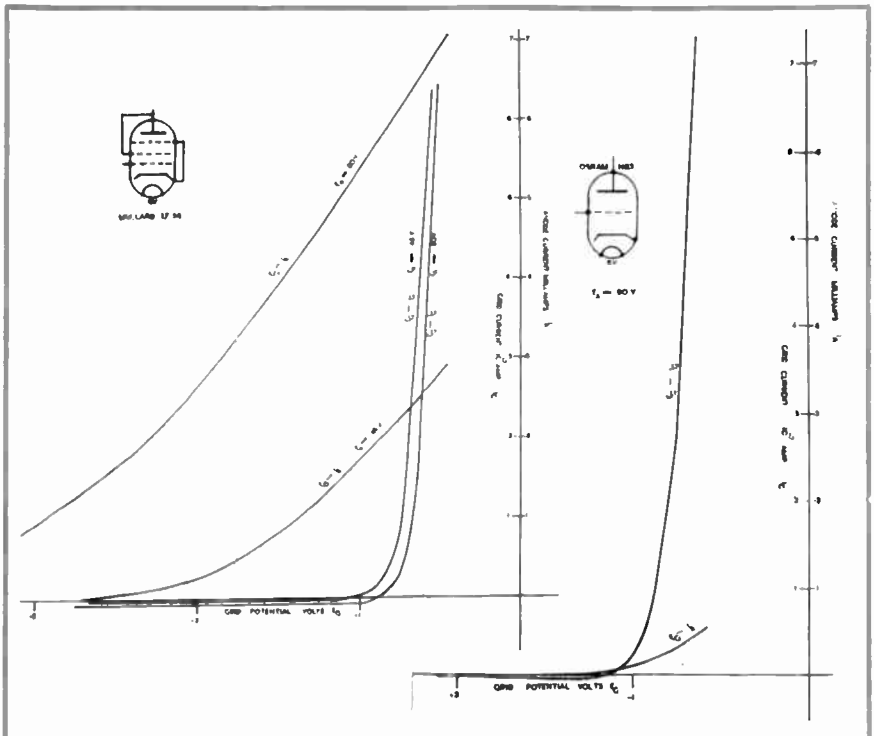

Fig. 3 (left). Characteristic curves for triode-connected EF36 valve showing relationship of grid current and anode current at different values of grid potential.

Fig. 4 (right). Characteristic curve of H63 triode showing relationship of grid and anode currents. (See text.)

ballistic and cannot be direct reading. These latter arrangements form the basis of most commercial instruments available to-day.

All these methods have disadvantages, and Penther and Rolfson[11] have produced a circuit which uses two valves in a balanced bridge circuit. The valves are adjusted to conditions of a very small grid current and then act in opposition. The instrument is mains operated but is still rather complicated.

Considering the basic diagram of Fig. 1 it will be realised that as long as the stray voltages produced in the circuit are constant their magnitude is of no importance whatever. Hence, although other workers have sought to reduce the grid current of the first valve of their electrometer circuits to negligible proportions there is no need to do so provided that it can be constant over the range of potential the electrode will give. If this is so the internal resistance of the electrode R_g will cause yet another constant potential E_g to be developed across the glass membrane which is the product of R_g and I_g, the grid current of the valve. This constant potential will not affect the operation of the instrument since it will merely introduce a zero error in the indicating meter which can easily be corrected by a backing of voltage or even adjusting the zero of the meter.

The requirement is therefore that it should be possible to find a valve with a high efficiency and a constant value of grid current for a wide range of applied potential to the grid. This was reminiscent of the constant anode current with variation of applied anode voltage so characteristic of pentode construction and a typical H.F. pentode valve, Mullard type EF36, was examined for its grid current characteristic. The valve was connected as a triode as shown in the key to Fig. 3 which gives the characteristics of the valve when operated at 45 and 90 volts anode potential, with the screen grid connected to the anode and the suppressor grid connected to the cathode.

It will be seen from the curves that using an anode voltage of 90 the grid current curve passes through the zero grid-current potential point at 0.9 volt and is then parallel with the abscissa and at a constant value of grid current, when the applied grid potential is more negative than this voltage.

In this case the cathode emission was nearly at its normal value as the heater was connected to a 6-volt supply and the valve is designed for a heater voltage of 6.3 V at 0.2 amp.

If the suppressor grid is connected to the anode as well as the screening grid the curve for grid current/grid potential is still flat at values of grid potential more negative than 1.0 volt but the grid current is greater, as would be expected.

When the EF36 valve is connected as a triode in the manner shown in the key to Fig. 3 it has an impedance of approximately 10,000 ohms and a mutual conductance value of 2.8 mA/V. This valve resembles an "L" type triode such as the Osram L63 which has, however, a higher grid current owing to the absence of a suppressor grid. This valve is unsuitable for use in electrometer circuits of this type where the electrode resistance is higher than about 40 megohms and also has the disadvantage of the control grid connexion being made by means of a pin in the base instead of a top cap as in the EF36.

The "H" type of triode valve is quite unsuitable in this connexion as the curves of Fig. 4 demonstrate. Not only is the grid current high but the available anode current is necessarily small.

The grid current in this case becomes zero at a value of anode current of less than 100 microamperes, and at values above this is positive and high. This valve is therefore useless since the only usable part of the grid current/grid potential curve of the anode current is too small to be of any value without amplification.

The remarkably constant grid current value obtained for the triode-connected EF36 valve is not an effect due to a fortunate valve as it has been confirmed on many other valves of the same make and type.

This valve makes the design of a valve voltmeter to measure the potential of glass electrode systems a simple matter, since it is now only necessary to choose an operating point on the anode current/grid potential curve such that the change due to the voltage from the electrode caused by a maximum pH difference of 14 pH units together with the residual constant voltage due to the grid current flowing through the electrode resistance, the asymmetry potential and other stray constant potentials will result in a linear change in the anode current and at the same time be within the range of constant grid current.

Under these conditions the anode current of the valve will vary linearly with the *pH* of the solution in the electrode spiral provided that the residual constant anode current is eliminated by a backing off current flowing through the meter in opposition to it. Furthermore, and an important point, by adjusting the sensitivity of the anode current meter it will be possible to arrange that any definite *pH* interval may subtend a full-scale deflection of the pointer.

It should be obvious that if the grid of the EF36 valve is connected directly to the source of negative voltage which governs the operating point, the meter in the anode circuit may read any value according to the setting of the backing circuit, and the value it does read is of no consequence.

Not only is it now possible to make a very inexpensive meter to read *pH* directly but there is no reason why a continuous recorder should not be made upon a sensitive recorder such as the Siemens single colour recorder or Cambridge single thread recorder.

At this juncture it may be well to return to the question of temperature errors mentioned above. It is the author's experience that very many applications of *pH* meters in process control require a rapid determination of continuous indication accurate to 0.1 *pH*. If a meter reading from 0 to 14 *pH* is fitted in a circuit of this type, even using a 6-in. scale, it will only be possible to interpolate to 0.05 *pH*, which corresponds to 5 per cent. of a *pH* unit which is equivalent to a change of 10° C. in temperature. Hence, provided that the instrument is calibrated at a common laboratory temperature compensation for temperature changes will be unnecessary. Further information upon this point is given in the appendix.

An appendix is given describing the preliminary instrument made by Mr. Sharland in these laboratories. Arrangements have been made with Messrs. Muirhead & Co., Ltd., of Elmers End, Beckenham, to have such an instrument made commercially available.

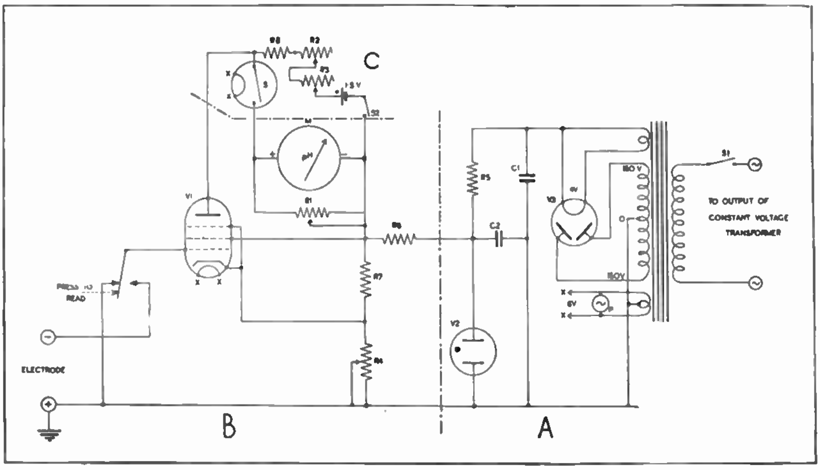

Fig. 5. Circuit of direct-reading valve voltmeter for the measurement of E.M.F.s from high resistance sources.

Component Values

R_1	1,000 ohms wirewound.	S_1	Single pole switch.
R_2	5,000 ohms wirewound.	S_3	6 V thermal delay switch.
R_3	500 ohms wirewound.	V_1	Mullard EF36.
R_4	200 ohms wirewound.	V_2	Mullard 4687.
R_5	15,000 ohms, 5 watts, wirewound.	V_3	Mullard AZ31.
R_6	4,000 ohms, 2 watts, wirewound.	Meter:	Taylor Model 600, 0–100 microamps.
R_7	5,000 ohms, 2 watts, wirewound.	Transformer:	230 V, primary.
R_8	500 ohms wirewound.		150–0–150 V } secondaries.
C_1	8 μF, 300 V working.		3–0–3 V } secondaries.
C_2	16 μF, 250 V working.		4 V } secondaries.

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APPENDIX

Description of a mains-operated direct-reading *pH* meter constructed upon the constant grid current principle

Details of the circuit of the instrument are given in Fig. 5, together with a table of component values.

Description

It will be seen that the circuit is divided into three sections, A, B, C, for ease of description.

Section A is the power supply circuit and is a normal radio type of rectifying circuit giving 150 V at 40 milliamps and supplying a neon voltage stabiliser V_2 which gives a constant voltage output of 85.

Section B is the constant grid current electrometer circuit comprising an EF36 valve which, in this case, is operated at 45 volts, anode potential supplied through the meter M which gives a full-scale deflection for 100 microamperes and can be shunted to a variable amount by the resistance R_1. The grid potential of the valve is derived from the potentiometer composed of the three resistors R_4, R_6, R_7, and is set at 1.0 volt negative by means of the adjustment of R_4. The glass electrode is connected to the grid of the EF36 valve in series with the bias potential at the time of reading by the press-button switch, which normally connects directly between the grid of the valve and the negative grid potential. The type of this switch is important as a high leakage resistance is essential and the component specified is very suitable.

Section C comprises the backing-off circuit to counteract the steady anode current due to the constant potential applied to the grid of the valve. This circuit is battery operated since a separate rectifier would be needed for mains operation. The large capacity 1.5-volt dry cell has a very long life as the current drain is so small. The thermal delay switch is included to prevent possible damage of the meter by the flow of current from the backing-off circuit before the EF36 valve has heated to full emission.

The meter is a 100-microampere movement with a 6-in. scale divided into ten parts corresponding to 0 to 10 *pH* units and each is further sub-divided to correspond to 0.1 *pH* unit.

Construction is straightforward and follows normal radio practice. The leads to the electrode should be taken via a concentric screened plug and socket in order that dip-type electrodes may be used. Screening is not necessary with the lower resistance spiral electrodes.

Method of Operation

The valve voltmeter is calibrated at a common laboratory temperature so that the *pH* unit equivalent in millivolts at that temperature applied to the input terminals from a potentiometer causes a deflection of the meter pointer of 1 *pH* interval on the scale. The actual position of this interval on the scale is unimportant. The adjustment for this calibration is the resistance R_1 and once this is set it should not need further adjustment.

It is then only necessary to set the scale when putting the meter into use. This is done by the user before taking reading on solution of unknown *pH*. A buffer solution of known *pH* is put into the electrode and by adjusting R_2 and R_3 the pointer is arranged to read the *pH* of this known buffer. If the calibration is accurate the meter will then give correct readings for other values of *pH*, but since the glass electrode is not a primary standard for *pH* measurement it is advisable to check the scale intervals from time to time in the following manner.

After setting the pointer by means of a known buffer solution a second buffer solution is used of considerably different known *pH* and, if the calibration is correct and the temperature within 10° C. or so of that at the time of calibration, the scale reading should correspond with the *pH* of this second buffer. How often this is done will depend on the views of the user but it need not be done very frequently, although it is necessary to check the setting of the pointer with a standard buffer before any tests or series of tests of unknown *pH*.

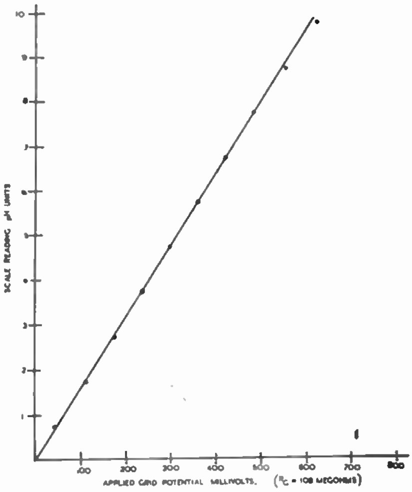


Fig. 6. Graph showing relationship between scale readings and applied potential from a source having a resistance of 108 megohms. The slight departure from linearity at the top of the curve could be corrected by using a higher anode voltage than 45 volts for the EF36 valve.

It may be found, as is the case in these laboratories, that a constant voltage transformer is needed to ensure stable operation if the mains are subject to considerable voltage fluctuation.

Results

The curve of Fig. 6 shows the relationship between the potential applied to the instrument and the scale readings and it will be seen that the scale is a linear one. Moving the controls R_2 and R_3 result in a shift of the curve along the abscissa without altering the slope in any degree so that the zero of the meter can correspond with any *pH* value.

Using a constant voltage transformer as mentioned above, the instrument gives repeatable readings without alteration of the setting for periods of hours and hence is eminently suitable for use with a recorder.

Some Possible Improvements

From a practical point of design there are improvements which might be made. The instrument could be made more compact by using a constant voltage step-down transformer for the 6-volt heater supply as in all probability the neon stabilisation of the anode potential is adequate. Metal rectification might prove more advantageous in such a small power supply unit as the transformer required is simpler.

Radio Equipment in the V2

From a lecture given by Wing Commander A. G. Pither, Director of Radar, R.A.A.F., to the Australian I.R.E.

The first rocket which arrived in England contained very complex radio equipment.

Later it was found that one transmitter and two receivers only were employed. This radio equipment was used to measure the velocity of the projectile and to cut off the fuel when a predetermined velocity had been reached. The measurement of velocity was made by means of the Döppler principle, the controller on the ground having a transmitter and receiver which worked with the correspondency receiver and transmitter in the projectile.

C.W. transmission was made from the ground transmitter at a frequency of approximately 30 Mc/s.

The frequency received by the projectile receiver was less than 30 Mc/s. owing to the fact that the receiver was moving away from the transmitter at very high speed. Assuming this frequency to be 30 Mc/s. less 300 c/s., one may calculate the projectile velocity in the following manner. Velocity of radio waves, 200,000 miles per second approx. This is equivalent to 30,000,000 radio waves per second. A loss in frequency of 300 cycles therefore represents a speed of

$$\frac{300}{30,000,000} \times 200,000$$

miles per second, or 7,200 m.p.h.

In actual practice the signals received by the projectile were doubled in frequency and retransmitted to the ground at about 60 Mc/s.

The controller had a suitable frequency meter, probably of the cathode-ray type, from which he could measure the speed direct. When the calculated speed was reached a second ground transmitter was employed to send control signals to the second projectile receiver, cutting off the power. This system of control was open to the very grave risk of jamming by the enemy. Soon after V2 came into use it was found that numbers of them arrived without radio equipment of any kind, and it was later discovered that an integrating accelerometer was used to produce the necessary control. This device automatically recorded the increase in velocity and switched off the fuel when a suitable value was reached.

The Design of Iron-Cored Transformers with Specified Self and Mutual Inductances

By J. O. G. BARRETT, B.A.*

1. Summary

THE purpose of this article is to indicate a method by which two inductances can be wound on a single iron core, so that both the self inductances and the mutual inductance can be easily adjusted to predetermined values.

It is found that if two coils be wound, one on each of the two side limbs of a suitable E and I type lamination, then the mutual inductance between them is approximately independent of the air-gap in the iron circuit and depends only on the lamination used. The self inductances of the coils, of course, vary with the gap.

If now two coils L_1 and L_2 are wound on one limb, and one coil, L_3, on the other, then, by adjusting the relative magnitudes of L_1, L_2 and L_3, and choosing the right direction of winding, it can be arranged that the series combination of L_1 and L_3, and the single coil L_2 shall have any desired values, while the coupling factor can be controlled over the whole range from practically zero to practically 100 per cent.

A few typical examples of the usefulness of this type of transformer are discussed and the measured results of a production batch are given.

2. Coupling between Coils on the Side Limbs of an E and I Lamination

Consider the lamination sketched in Fig. 1. The cross-sections of the side and centre limbs are A_1, A_2 and the lengths l_1, l_2 as shown. Let the flux, due to the current in a coil wound on the limb AB, be ϕ_2 in the centre limb DC and ϕ_1 in the limb EF; then the flux in AB (ignoring leakage) is obviously

$$\phi = \phi_1 + \phi_2$$

The total M.M.F. round the closed circuit $DCFED$ must be zero, so that we have, if a is the gap and μ the permeability,

$$\phi_2 \frac{l_2/\mu + a}{A_2} - 2\phi_1 \frac{l_1/\mu}{A_1} - \phi_1 \frac{l_2/\mu + a}{A_1} \text{ becomes zero} \quad ...... (1)$$

$$i.e., \frac{\phi_2}{A_2}\left(\frac{l_2}{\mu} + a\right) = \frac{\phi_1}{A_1}\left\{\frac{2l_1 + l_2}{\mu} + a\right\}$$

$$\therefore \frac{\phi_1}{\phi_2} = \frac{(l_2/\mu + a).A_1}{\left\{\frac{2l_1 + l_2}{\mu} + a\right\} A_2}$$

and

$$k_1 = \frac{\phi_1}{\phi_1 + \phi_2} = \frac{\phi_1}{\phi} = \frac{1}{1 + \frac{A_2}{A_1} + \frac{2l_1}{l_2 + \mu a}\cdot\frac{A_2}{A_1}} \quad ......(2)$$

Now k_1 $\left(i.e., \frac{\phi_1}{\phi}\right)$ is the coefficient of coupling of two coils wound on AB and EF.

It is interesting to examine briefly the limiting values of k_1 for $a = 0$ and $a = \infty$ in Equation (2).

Putting $a = 0$, we have:

$$k_{1\,min} = \frac{1}{1 + \frac{A_2}{A_1}\left(1 + \frac{2l_1}{l_2}\right)} \quad ...... (3)$$

and putting $a = \infty$

$$k_{1\,max} = \frac{A_1}{A_1 + A_2} \quad .... (4)$$

It should be noticed that these values will never be attained in practice, for Equation (3) assumes no effective gap whatsoever, while Equation (4) assumes that the flux travels across the infinite gap without any spreading.

A particular lamination (Telcon 36T) has the following dimensions: $l_1 = 2.1$ cms., $l_2 = 3.2$ cms., $A_2 = 1.1$ cms., $A_1 = 0.65$ cm. (It is permissible to take the cross-sections as the width of the limbs, since they always occur in the equations as a ratio.)

Then we find from (3) and (4):

$$k_{1\,max} = \frac{0.65}{1.75} = 0.37$$

* The Plessey Co., Ilford.

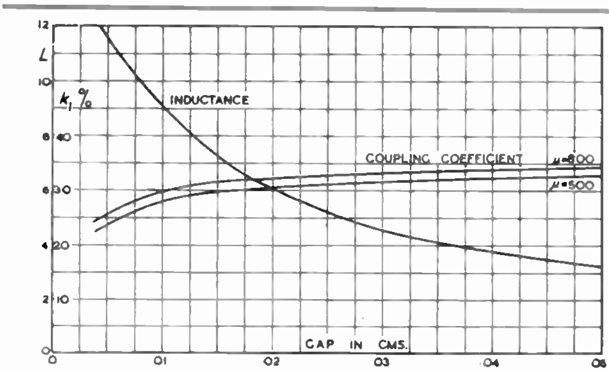


Fig. 2.

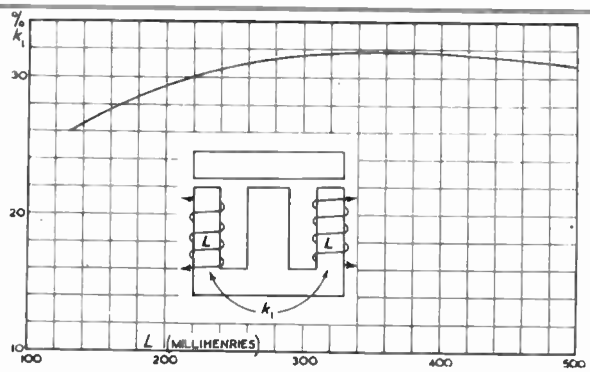


Fig. 3.

and

$$k_{1\,min} = \frac{1}{1 + \frac{1.1}{0.65}\left(1 + \frac{2 \times 1.1}{3.2}\right)} = 0.204$$

As has been stated above, these values are unrealisable extremes, and it is now necessary to evaluate Equation (2) for a range of values of α; in order to do this, we must assume a value for μ. The laminations used were Rhometal, for which μ was approximately 600, and Fig. 2 shows the result of plotting k_1 against α for the lamination specified above and using two values of μ—*i.e.*, 800 and 500.

It is clear that, over a fairly wide range of gaps, the coefficient of coupling does not vary very much.

It is now necessary to investigate the self inductance variations of the same coils over a similar range of gaps.

Using Fig. 1 again, we have, for the total reluctance of a coil wound on a side limb:

$$\mathcal{R} = \frac{2l_1 + l_2 + \mu\alpha}{\mu A_1} + \frac{(l_2 + \mu\alpha)(2l_1 + l_2 + \mu\alpha)}{\mu A_2(2l_1 + l_2 + \mu\alpha) + \mu A(l_2 + \mu\alpha)}$$

Put

$$\frac{2l_1 + l_2 + \mu\alpha}{\mu A_1} = x \text{ and } \frac{\mu A_2}{l_2 + \mu\alpha} = y$$

Then

$$\mathcal{R} = x + \frac{1}{y + \frac{1}{x}} = x + \frac{x}{1 + xy}$$

Hence the permeance, which, when multiplied by the appropriate factor, gives the inductance, is:

$$\mathcal{P} = \frac{1}{\mathcal{R}} = \frac{1}{x + \frac{x}{1 + xy}} = \frac{1 + xy}{x(2 + xy)}$$

If we now assume the previous values, *i.e.*, $A_1 = .65$, $A_2 = 1.1$, $l_1 = 2.1$, $l_2 = 3.2$, $\mu = 500$, we can calculate the value of $\mathcal{P}$ for various values of α, and thus obtain a curve which represents the variation of self inductance with gap. This curve is shown in Fig. 2 along with the coefficient of coupling. The units of inductance are, of course, arbitrary, depending on the turns used in the coil.

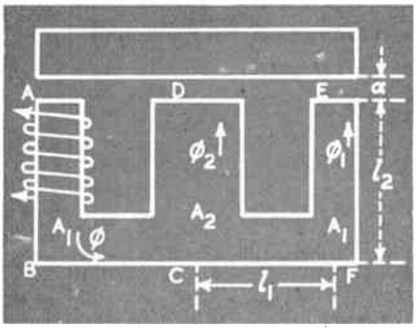


Fig. 1.

In Fig. 3 is shown the measured variation of percentage coupling plotted against inductance; it is clear that a considerable change in inductance is possible for a very small change in percentage coupling, and that, were a transformer required with this particular coefficient of coupling, *i.e.*, about 32 per cent., it would be possible to adjust the primary and secondary inductances closely by altering the gap, without, at the same time, varying the coefficient of coupling between them.

In general, however, it is desirable to be able to obtain any specified arbitrary value of coupling and inductances, and this problem is discussed in the next section.

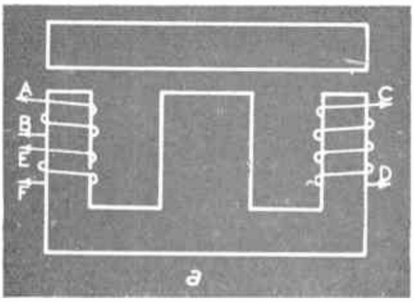


Fig. 4a.

3. Three-Coil Transformer with Coils wound on Side Limbs of Lamination

Consider three coils AB, CD, EF, wound on the two side limbs of an E and I type lamination as shown in Fig. 4a, and suppose them to be connected as in Fig. 4b. Let the self inductances be L_1, L_2 and L_3 and let the coefficient of coupling between coils on the same limb be k, and that between coils on the outer limbs be k_1.

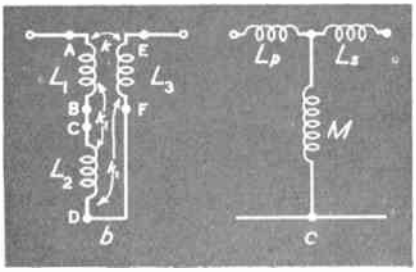


Fig. 4b. Fig. 4c.

Now Fig. 4b is a transformer and can, therefore, be represented by the equivalent circuit of Fig. 4c. We will now find the relations between L_1, L_2, L_3, k and k_1 of Fig. 4b and L_p, L_s and M of Fig. 4c.

Assume the directions of winding to be such that AB, CD are series-opposing, while AB, EF are series-aiding.

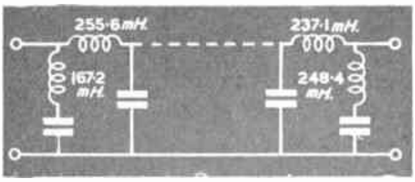


Fig. 5.

Then we have, if the networks of Figs. 4b and 4c are equivalent:

$$M = k\sqrt{L_1L_3} - k_1\sqrt{L_2L_3} \quad \ldots\ldots \quad (5)$$

$$L_p = L_1 + L_2 - 2k_1\sqrt{L_1L_2} - M \quad (6)$$

$$L_s = L_3 - M \quad \ldots\ldots\ldots\ldots \quad (7)$$

Putting $k = 1$, we get from (5), on rearranging:—

$$\sqrt{L_1} = M/\sqrt{L_3} + k_1\sqrt{L_2} \quad \ldots\ldots\ldots \quad (8)$$

or

$$L_1 = M^2/L_3 + 2k_1M\sqrt{L_2/L_3} + k_1^2L_2 \quad \ldots\ldots\ldots \quad (8a)$$

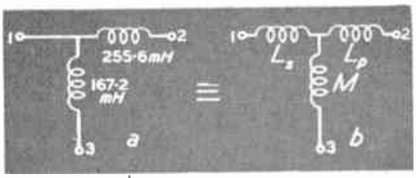


Fig. 6a. Fig. 6b.

Substituting in (6) for L_1, we obtain

$$M^2/L_3 + L_2(1 - k_1^2) - M = L_p$$

$$i.e., \; L_2 = (M + L_p - M^2/L_3)/(1 - k_1^2)$$

Using Equation (7), $L_3 = L_s + M$ (9)

and

$$L_2 = \frac{(M + L_p - M^2/L_s + M)}{(1 - k_1^2)} \quad \text{......... (10)}$$

Thus Equations (9) and (10) give L_3 and L_2 in terms of L_p, L_s, M and k_1.

In practice L_1 is most easily obtained from Equation (8), but, for the sake of completeness, it may be expressed in terms of L_p, L_s, M and k_1, by using (9) and (10):—

$$L_1 = \left\{ \frac{M}{L_s + M} + k_1 \sqrt{\frac{M + L_p' - \dfrac{M^2}{L_s + M}}{1 - k_1^2}} \right\}^2 \quad \text{...... (11)}$$

Clearly the sign of k_1 affects the value of L_1 only, and assuming that the appropriate method of interconnecting the coils is used, then k_1 may be taken as positive or negative according to which sign gives the most convenient value for L_1.

4. Application and Results

A typical example of the use of the above transformations is perhaps of interest.

A bandpass audio filter had been designed, the two end half-sections being as shown in Fig 5.

Taking the two left-hand coils, we equate the networks shown in Figs. 6a and 6b.

Clearly $L_s = 0$, $L_p = 255.6$, $M = 167.2$ mH.

We now apply Equations (8), (9) and (10) and derive values for L_1, L_2 and L_3 of Fig. 4b, which will give a network identical with Fig. 6a.

A preliminary measurement showed that the best value to take for k_1 was 28.2 per cent.—that is, rather lower than the calculated figure. The departure may be due either to various assumptions made in the calculation, or to uncertainty as to the correct effective value to be taken for the permeability.

Using this value of k_1, we have the following:—

From (9) $L_3 = L_s + M = 167.2$ mH.

From (10)

$$L_2 = \frac{M + L_p - \dfrac{M^2}{L_s + M}}{1 - k_1^2}$$

$$= \frac{255.6}{0.9205} = 277.8 \text{ mH}$$

From (8) $\sqrt{L_1} = M/\sqrt{L_3} - k_1\sqrt{L_3}$

$$= \frac{167.2}{12.91} - 0.282 \times 16.65$$

$$= 12.95 - 4.7 = 8.25$$

$$\therefore L_1 = 68 \text{ mH}$$

It will be noticed that, in applying Equation (8), we have taken k_1 as negative; if we take the positive sign, we get $L_1 = 312$ mH.

Now L_1 and L_3 are wound on the same limb, and hence it is convenient to have as small a value as possible for L_1, both for efficiency and ease of winding.

We now have the required inductances for L_1, L_2 and L_3 and next calculate the turns required. It was found that 700 turns on a side limb gave an inductance of 100 mH, and hence we find the turns for the coils required as:—

$L_1 = 68$ mH 576 turns.

$L_2 = 277.8$ mH 1,170 turns.

$L_3 = 167.2$ mH 906 turns.

These turns are actually derived by assuming that the inductance is proportional to the 1.99^{th} power of the turns.

A transformer wound to the above turns gave the following values of inductance, the subscripts referring to Fig. 6a.

$L_{1-2} = 257.2$ mH.

$L_{1-3} = 166.45$ mH.

$L_{2-3} = 420.4$ mH.

These figures were obtained after the gap in the iron circuit had been adjusted until L_1 and L_2 had nearly the correct values. The errors involved are, as will be seen on comparing these figures with Fig. 6a, of the order of 0.5 per cent.

By an exactly similar method, the right-hand pair of coils in Fig. 5 can be replaced by a transformer, having $L_1 = 127$ mH, $L_2 = 257.5$ mH, $L_3 = 248.4$ mH, where L_1, L_2 and L_3 have the same meaning as in the previous example. The gaps were adjusted so that $L_3 = 248.4$ and $L_2 = 257.8$ mH, and then the various composite inductances measured. With the same notation as is used in Fig. 6b, the values were:—

$L_{1-2} = 238.6$ mH.

$L_{1-3} = 485.2$ mH.

$L_{2-3} = 248.4$ mH.

The departure of the obtained inductances from those required in Fig. 5 are then seen to be 0.63 per cent. in L_{1-2}, 0.06 per cent. in L_{1-3} and zero in L_{2-3}.

The figures quoted above were obtained after the coils had been adjusted in the laboratory, though no extreme effort was made to obtain exactly correct values. Similar coils were later made and adjusted by production personnel, the following results (Tables 1 and 2) on six coils of each type indicating the errors to be expected in production samples.

These coils were adjusted by varying the gap so that L_2 and L_3 were nearly correct. The inductances L_{2-3}, L_{1-2} were then measured. The correct value is shown at the top of each column and it is clear that the agreement between desired and obtained values is in general very close.

TABLE

Transformer No.	L_2 277.8 mH	L_3 167.2 mH	L_{2-3} 422.8 mH	L_{1-2} 255.6 mH
1	279	167	423	260
2	278.6	167	423	255
3	277.4	167	420	256
4	278	167	421	256
5	278	168	422	257
6	278	167.8	420	255
R.M.S. error (%)	0.23	0.26	0.43	0.78

TABLE 2

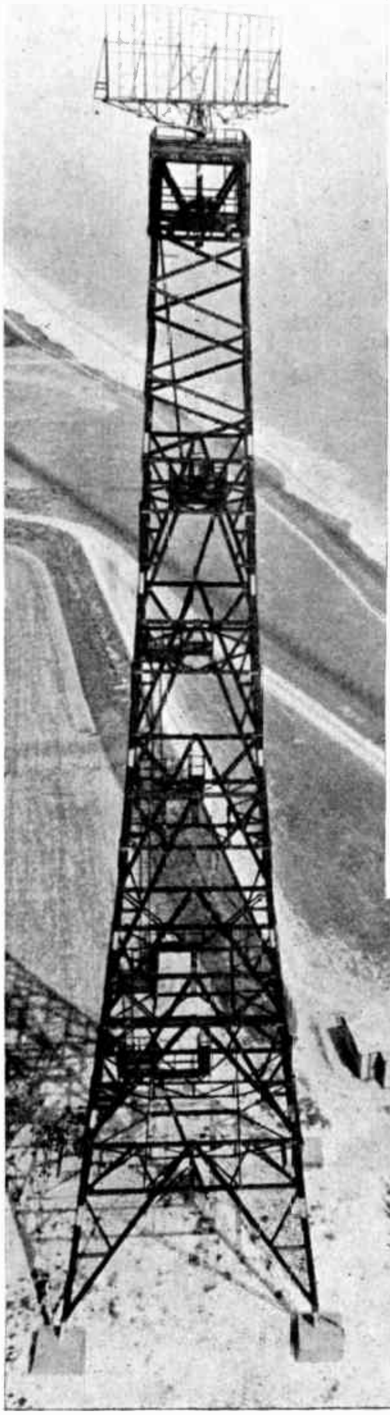
Transformer No.	L_2 257.5 mH	L_3 248.4 mH	L_{2-3} 285.5 mH	L_{1-2} 237.1 mH
1	257	248.6	287	240
2	257.3	248	284	239
3	257	248	287	239
4	257	248	288	240
5	257.5	248.8	288	238
6	257	248	285	237
R.M.S. error (%)	0.16	0.15	0.63	0.85

Acknowledgment

All the above work was carried out in the laboratories of The Plessey Company, Limited, by whose permission the data quoted are published.

Radiolocation : *An account of its development*

The following abstract of the 36th Kelvin Lecture given by **Sir Edward Appleton, K.C.B., M.A., D.Sc., LL.D., F.R.S.,** on April 26, 1945, at the Institution of Electrical Engineers gives an account of the scientific principles on which Radiolocation is based.




Aerial view of "CHAIN HOME" Radar Station intended to detect and report low-flying aircraft. The aerial array shown is 185 feet high and operates both as a transmitter and receiver.

RADIOLOCATION may be defined as the process of locating the position of an object in space by radio waves without any active co-operation on the part of that object. In other words, radiolocation enables us to find the position of a body, such as an aircraft, ship, iceberg, or ionised cloud, without going up to that body to find out for ourselves. The only co-operation required on the part of the detected body is of a passive character in that it is required to reflect radio waves. Fortunately, all solid and liquid bodies, as has long been known, do this. Since, moreover, radio waves are, in general, uninfluenced by darkness, clouds or fog, radiolocation can play the war-time role of an infallible sentinel for the detection of enemy air-borne or sea-borne units. The method of determining the distance of a radiolocated object is one of the most interesting features of radiolocation for it is a product of pure science, and involves the use of a technique developed twenty years ago with no thought of its present widespread practical application. The basis of the method is that the distance away of the located object is found by timing the journey of the radio waves to the reflecting object and back, just as seamen sometimes time an echo of a ship's whistle to determine roughly their distance from the face of a cliff. But the time scales of the two examples are vastly different. Radio waves travel with a speed of 186,000 miles per second, which is about a million times the speed of sound. Such waves therefore travel to and from an object 100 miles away in about one-thousandth of a second, and it is the accurate and speedy measurement of time intervals of this order which is the basic feature of radio measurement of distance.

The first experiments on the measurement of distance by radio reflections were carried out in 1924 by E. V. Appleton and M. A. F. Barnett in their experimental proof of the existence of the Heaviside Layer and the measurement of its distance above ground. In these experiments, which were carried out under the auspices of the Radio Research Board of the Department of Scientific and Industrial Research, the timing of the radio waves to the reflecting Heaviside Layer and back was achieved by changing the frequency of the waves by a known amount. Nowadays we should call their method that of frequency-modulation. It is no exaggeration, therefore, to say that the first object to be radiolocated was the Heaviside Layer. Shortly after Appleton and Barnett had finished their work, two American scientists, G. Breit and M. A. Tuve, working in Washington, succeeded in measuring the height of the Heaviside Layer using amplitude modulation of the radio waves. For this purpose they devised a radio transmitter which sent out very short pulses, or jabs, of radio energy and recorded the time interval between the emission of a pulse and the reception of its echo on a high-speed galvanometer. The pulse method, because of its simplicity, has been widely used later in the measurement of the distance of artificial targets such as aircraft and ships.

A particularly useful simplification in the technique of the pulse method was introduced in 1931 by E. V. APPLETON and G. BUILDER in the use of the cathode-ray oscillograph, with an associated uniform time-scale, by which the presence of a reflecting object and the indication of its distance away could be continuously portrayed to the eye without the need of developing photographs. By 1932, therefore, the technique of measuring the distance of atmospheric reflecting surfaces, such as ionised layers and ionised clouds, by means of radio pulses and cathode-ray oscillograph display was becoming standard research practice in this country.

Practical Radiolocation

But the application of these methods to the radio-detection of such relatively small objects as distant aircraft and ships by no means followed automatically. In 1932, however, the engineers of the British Post Office reported what is considered to be the first recorded instance of the detection of the presence of aircraft by reflected short radio waves. In the following year, engineers of the American Bell Telephone Laboratories published an account of experiments in which it was shown that aircraft reflected sufficiently appreciable quantities of radio energy to make it possible to detect their presence even when they were otherwise invisible. It remained to develop the military application of the position-finding of artificial objects by fusing both branches of knowledge and, in particular, by using higher-powered transmitters to extend the range of detection. This brilliant application of scientific principles to forge weapons of the highest operational utility was begun in 1935 by a small group of British scientists, MESSRS. L. H. BAINBRIDGE-BELL, E. G. BOWEN and A. F. WILKINS, led by SIR ROBERT WATSON-WATT, at an Air Ministry station on the East Coast of England. This effort, begun by this small nucleus, gradually expanded in volume and, as a result, this country was already provided with radiolocation sentinels for the detection of aircraft when war broke out in 1939.

Further Possible Developments of Scientific Radiolocation

The use of methods of radio distance finding by reflexion have already provided us with a vast fund of knowledge concerning the electrical reflecting layers in the upper atmosphere from which it is now possible to predict the most suitable wavelengths for use in communicating over various distances at different times in different parts of the world. Further work is now in progress in England on the location of meteor trails by means of radio reflexions. Another problem being considered is the possible radiolocation of the moon. Calculations show that with a very powerful sending station, and sharp focusing at the sending and receiving stations, it should be possible to get back detectable radio echoes after the radio waves have made their 2½-second journey to the moon and back.

The Pioneers of Radiolocation

A Speech by **Sir Stafford Cripps,** President of the Board of Trade and Chairman of the Radio Board, 1942–45, at a Press Conference on Tuesday, August 14, 1945

TO-DAY, by agreement with our American Allies, we reveal the story of an invention—Radar*—which has played a greater part in the war than the atom bomb itself.

We are giving publicity to the British achievements in this field. Our American Allies will be giving their publicity as to the part which they played. There is no competition for glory between our countries, for we have worked hand in hand over this matter. I shall tell you of those who have given their services in this country; our American friends will speak of their citizens who have also made great contributions.

Radar, more than any other scientific factor, contributed to the final victory over Germany, and now that we can concentrate our thoughts upon the problems of peace, we see that Radar possesses far more immediate potentialities for the service of the human race than the splitting of the atom. For you are going to benefit by the results of Radar at once, not only when you cross the Atlantic, but the first time you go up in an aeroplane.

I am very proud to speak to you to-day as chairman of the Radio Board from the autumn of 1942 until May, 1945. Air Chief Marshal Sir Arthur Tedder, out of his wealth of varied experience in many key positions, culminating in that of Deputy Allied Supreme Commander in the European Theatre, will follow me and tell you what Radar meant both strategically and tactically to the winning of the war. I want to give you some information on the research and development side, including the names of some of those to whom we are specially indebted for the work which made this great invention possible.

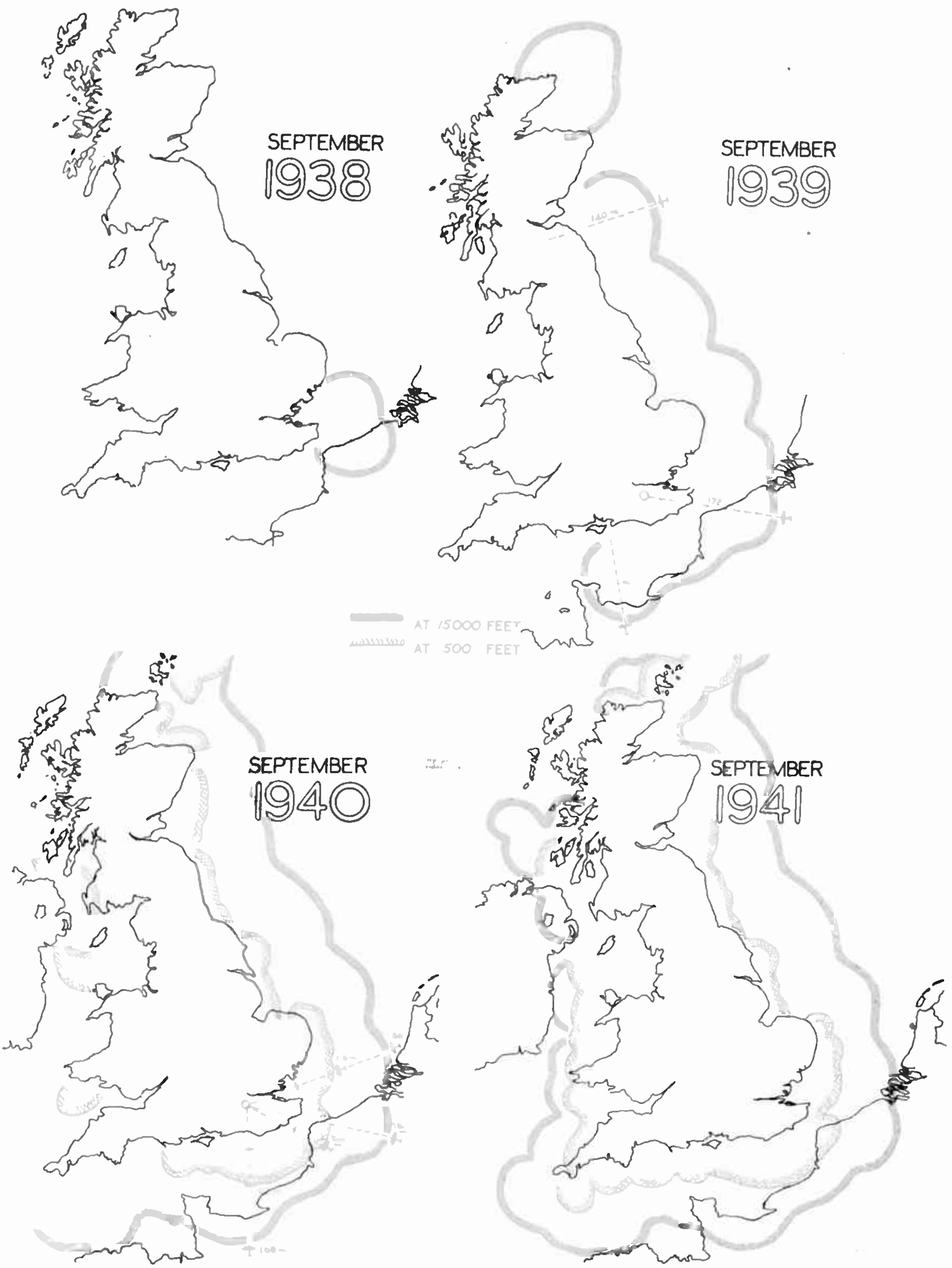
Had these men not been working upon this invention long before war broke out, it is doubtful, very doubtful indeed, whether we in this island would have been able to hold the fort in those critical years of our lonely struggle in 1940-41, when Germany threw the whole weight of her air armada against us and was trying with a considerable measure of success to cut our lifeline on the sea with her U-boats.

It was not unnatural that at about the time of Hitler's accession to power in 1933, the Air Staff and the scientists who were working with them began to be very worried because there was no known way of detecting the approach of aircraft at a distance and no way of seeing them or following their course in overcast weather or by night. H. E. WIMPERIS, the Director of Scientific Research at the Air Ministry, and A. P. ROWE, who was then his scientific assistant, urged the need for some new action to solve this problem, and action followed immediately.

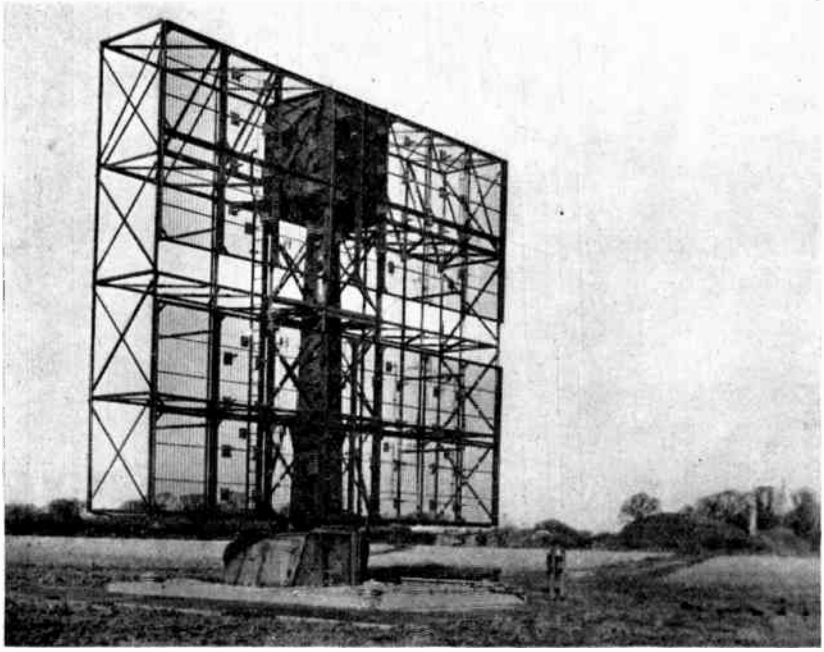
LORD SWINTON, who was then Secretary of State for Air, appointed a committee consisting of SIR HENRY TIZARD, PROFESSOR A. V. HILL and PROFESSOR PATRICK BLACKETT (three scientists with wide knowledge and experience) to work with the Air Staff and help them in solving these problems. Wimperis was also a member of the committee and Rowe was its secretary.

* This term, which is, of course, synonymous with Radiolocation, has been retained from the original text.—ED.

The Growth of Radiolocation



The four maps show the growth of Radiolocation coverage from the time of Munich to a year after the Battle of Britain. Note the introduction of detectors for low-flying in 1940, and the protection of the principal ports.



Above : A ground-controlled interception (G.C.I.) station, the transmitter and receiver being located below ground. This station directed fighters until they were close enough to the enemy for the A.I. equipment to be effective.

Below, left : Interior of the underground transmitter room.

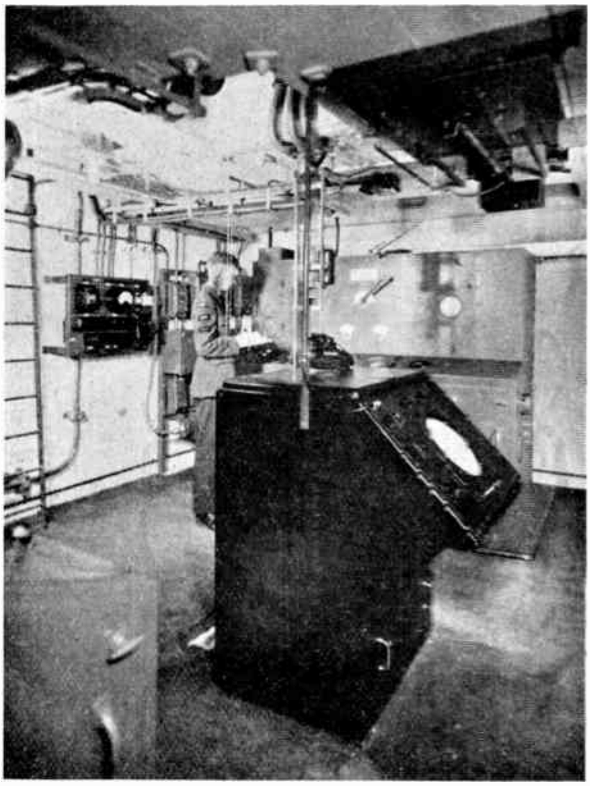
Below, right : The fighter direction aerial system with cabin mounted on the aerial structure to house both the transmitter and receiver.

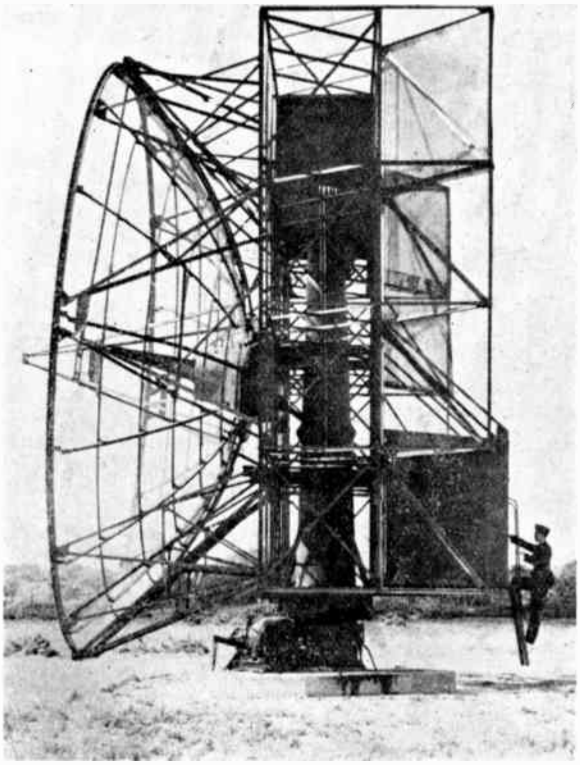
Proceeding from the possibilities opened up by the work of Appleton, Breit and Tuve, and his colleagues in the radio department of the National Physical Laboratory, it was R. A. WATSON-WATT (now Sir Robert Watson-Watt) who, early in 1935, produced the first practical and detailed proposals for locating aircraft by radio. From this moment started the development of Radar as we have come to know it.

From this point on, progress was rapid, considering the great complexity of the subject.

Within six months, by September, 1935, the first Radar station was in operation and aircraft approaching these shores were being located 50 miles away. This was the first installation anywhere in the world

By September, 1938, when danger to this country seemed acute, the range of detection had been increased to 150 miles. London was already reasonably protected against surprise in air attack and we had been able to make our whole air defence system more effective. On Good Friday, 1939, when the Germans marched into Prague, there began a 24-hour Radar watch along the whole coast from Scapa Flow to Portsmouth. In Sep-





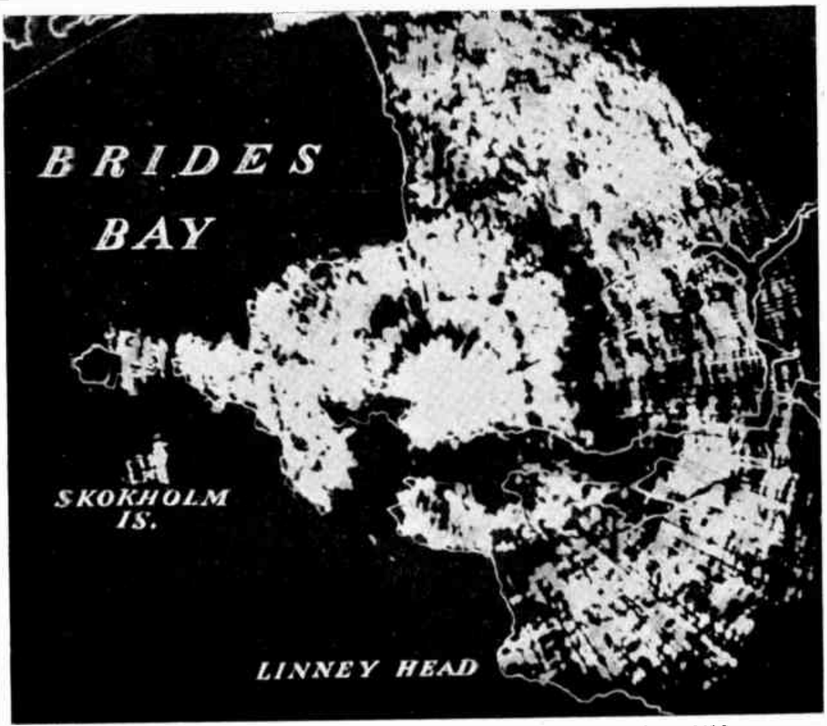
tember, 1939, when war broke out, the chain was complete.

Besides those whom I have already mentioned, other leading scientific workers in this first great step were two young members of the radio department of the National Physical Laboratory—A. F. WILKINS and E. G. BOWEN. Following their early work, Wilkins developed I.F.F., the complex method of identifying aircraft, friend or foe, while Bowen went on to pioneer work in airborne Radar.

The first big operational test of Radar, and the glorious proof of its success, came in the Battle of Britain, which history will surely record as one of the decisive battles of the world. For had we lost it, who can say how different might have been the course of the war?

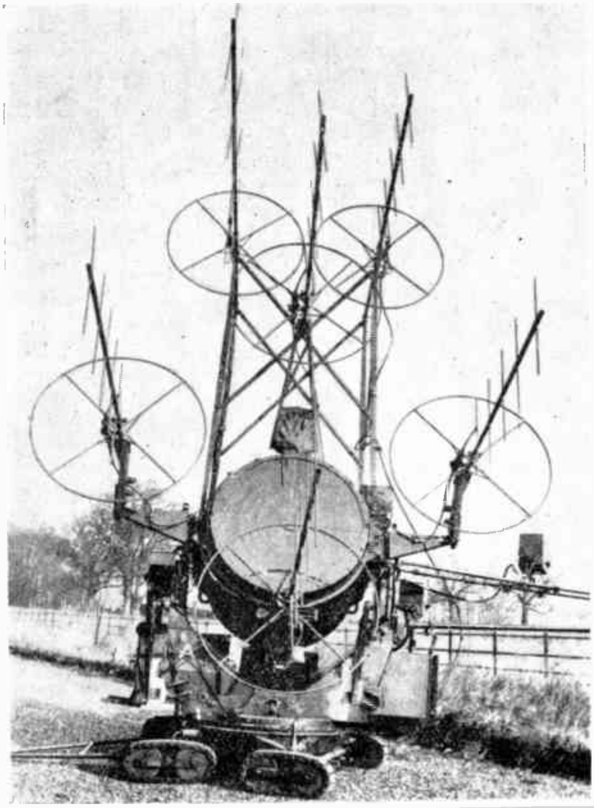
With the Battle of Britain by day we associate again the name of Sir Henry Tizard, who initiated the practice of controlled interception. It was he also who led the British Mission to the U.S.A. in 1940 which communicated the secrets of all our work on Radar to the American Government before they entered the war.

With the Battle of Britain by night must be associated the use of A.I., or Air Interception, which was begun by Bowen's team, and the use of G.C.I., or Ground Control Interception, which DR. DENIS TAYLOR developed, using the P.P.I. (Plan Position Indicator) for the first of its many applications. There was another important use for Radar to enable the searchlights spotting

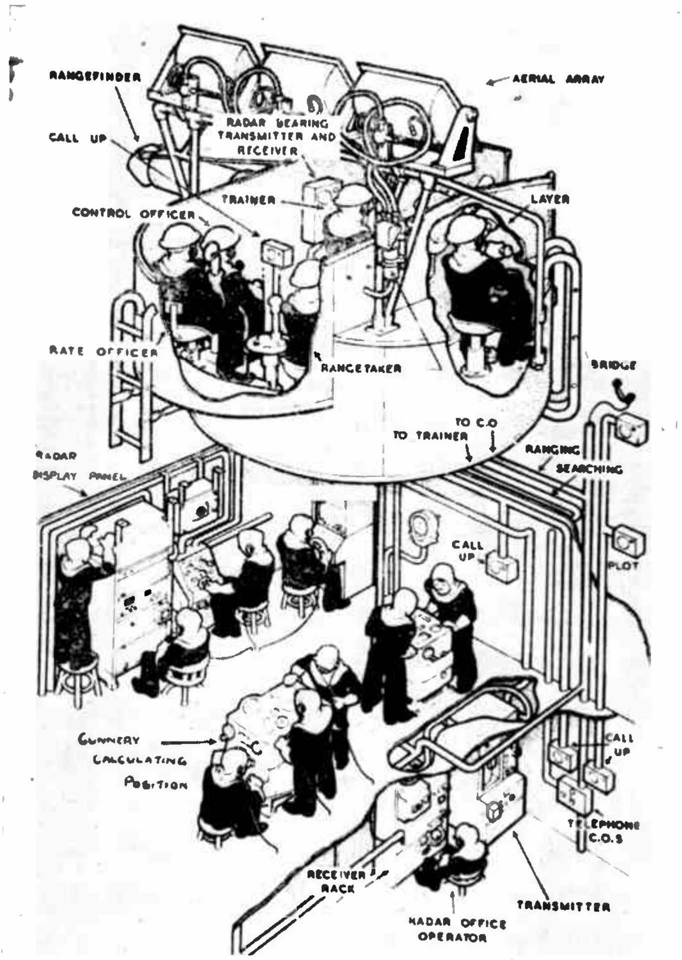


A remarkable Radar map of part of S.W. Wales seen on the screen of the H2S apparatus. This was taken during a test flight. Improved equipment gave even greater detail. Only the outline of the coast has been added to the photograph.

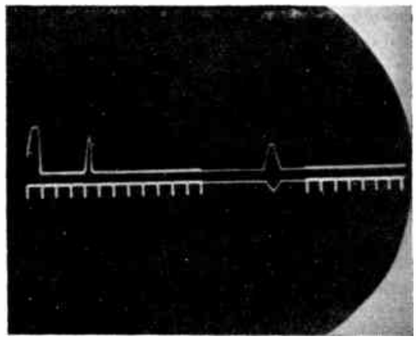
A modern Radar-controlled A.A. searchlight equipment used in shooting down night bombers. This was extensively used during the flying bomb attack in 1944. *Below, left*: A.T.S. Predictor Detachment at action stations.



NAVAL RADAR



Left: **Operation of Radar in naval gunnery. The range is transmitted by the operator (bottom) to the gunnery calculating position. The layer and trainer in the gun director transmit the bearing. If the target is out of sight, the Radar display panel is used.**



Right: **Radar rangefinder. The target is shown by the inverted 'V' and the lower 'V' is matched to it to determine the range.**

enemy aircraft to open straight on to their target. This was known as Elsie (S.L.C.) and was largely the work of HAROLD LARNDER and W. S. EASTWOOD.

So far I have spoken only about the applications of Radar to air defence, which was its earliest and most obvious use. But during this time great strides were being made in its applications to the needs of the Navy and Army.

Since before the war, DR. W. S. BUTEMENT had been working on Radar to locate ships as targets for coast defence artillery, and had made a very great advance in directional accuracy. At the same time P. E. POLLARD was proving that Radar range-finding was more accurate in dealing with aircraft than the big optical range-finder. From Butement's work came the coast artillery Radar and the C.H.L., essential to air interception of the low-flyer; from Pollard came the G.L. set for unseen A.A. fire.

Meanwhile the Navy, having developed air warning sets for its ships, went on to development of Radar for fire control. C. E. HORTON was a leader in these developments, while J. F. COALES made noteworthy contributions to gunnery Radar, which was eventually to play such an important part in sinking the *Bismarck* and the *Scharnhorst*.

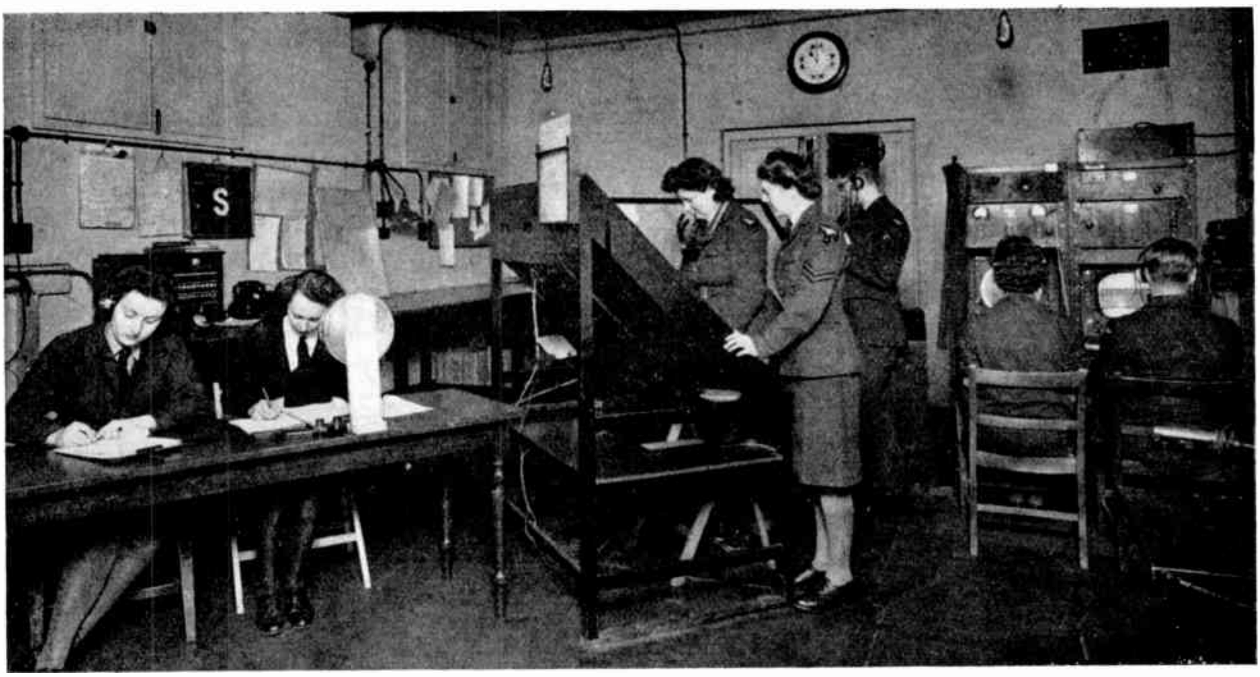
Radar was also brought into effective use in the anti-U-boat war. BOWEN and R. HANBURY-BROWN were two of the scientists who were prominent in the development of the early airborne sets for locating surface ships and surfaced submarines.

But all this, decisive as it proved in defence, was only a beginning. From the earliest days it had been realised that greater accuracy, and in particular the capacity to discriminate between the echoes from natural objects and those from the target, were required. Nothing but a narrow beam instead of the former "floodlighting" technique could give the results desired, and this meant much shorter wavelengths on high powers and high sensitivity.

Fortunately, we were well placed to deal with this problem. From March, 1939, 90 of our leading physicists, had been attached to the stations of the coastal chain. Their past experience had made them peculiarly receptive to the need for the short centimetric waves and resourceful in meeting it.

PROFESSOR M. L. OLIPHANT, of Birmingham University, supported by DR. H. W. B. SKINNER, of Bristol, inspired their co-workers by their insistence upon the urgent need for centimetric wavelengths and by their own experimental skill. A tremendous drive followed until in July, 1940, PROFESSOR J. T. RANDALL, of Birmingham, produced a magnetron which was the first high-power generator of centimetric waves in the world. The magnetron remains the heart of every modern Radar equipment.

This new tool was eagerly seized upon by the Radar researchers. It was supplemented by an equally novel receiving valve evolved by DR. R. W. SUTTON. The result was a centimetric ground Radar set. This in turn became the precursor of the shipborne set vital to the war against the U-boat and the centimetric G.L. equipment. DR. LANDALE was responsible for the shipborne set, while PROFESSOR JOHN COCKCROFT and DR. E. S. SHIRE were responsible for the centimetric G.L. equipment. This work was mainly shared out among the three Government research establishments, Admiralty Signals Establishment, under CAPTAIN B. R. WILLETT and then under CAPTAIN T. W. B. BROOKING, the Air Defence Research and Development Establishment (now the Radio Research and Development Establishment) of the Ministry of Supply under JOHN COCKCROFT, C. W. OATLEY and O. G. SUTTON successively, and the Telecommunications Research Establish-



Interior of the "Chain Home Low" receiver room.

ment of M.A.P. under A. P. Rowe, to whom I referred earlier on.

Then came the centimetric version of A.I., the device carried in the night fighters which enabled the pilot to direct himself straight on to the enemy bomber. PROFESSOR P. I. DEE, ALLEN HODGKIN and W. E. BURCHAM were the leading figures in this development.

The same technique gave us, in the hands of Dee and his team, a centimetric A.S.V., the device carried in Coastal Command aircraft which directed them to the surfaced U-boat and which, together with its ship-borne brother in destroyer and corvette, finally led in the Battle of the Bay of Biscay to the defeat of the U-boat, at a time when it seemed as if the whole of our war effort might be strangled by their activities.

Further slight changes at the hands of Dee, Skinner, A. C. LOVELL and others produced the first H.2.S set. This truly remarkable device, which shows visually in the heavy bomber a continuous picture of the unseen ground over which it is passing, made the ruins of Hamburg and Berlin its monument. DENIS ROBINSON also made his contribution to the A.S.V. and H.2.S projects.

Finally, there were three remarkable further aids to our offensive which were being developed at about the same time:

Gee

The navigational system which enabled our bombers to know exactly where they were at any time *en route* to or from Germany. It was this device which made the 1,000-bomber raids possible and which increased the effectiveness of our bombing some three- or five-fold. On D-Day it was the universal navigational aid, for sea and air alike, so much so that it has been suggested it should have more appropriately been called Gee-Day. Gee was thought up and developed by R. J. DIPPY, with the help of C. C. E. BELLRINGER.

Oboe

The system which gives the bomber its position even more exactly than Gee and by means of which the signal to drop its bombs on the target in Germany was given from the base in England. It provided the means of silencing alike the factories of the Ruhr and the coastal guns of Normandy. F. C. WILLIAMS, A. H. REEVES and F. E. JONES were responsible for the development of this most ingenious device.

Rebecca-Eureka

By this means our airborne forces were enabled to direct themselves to any given point in hostile country where an advance party had already installed a "Radar beacon." The system was devised by Williams, developed by J. W. S. PRINGLE, and nursed into operational use by A. W. LINES.

There are countless other names which I should mention if I am to do full justice to the many hundreds of men, and women too, who contributed to the research and development of these outstanding discoveries. There were those, for instance, whose names were not peculiarly identified with any special device, but who contributed to the general pool of knowledge and experience out of which the individual devices grew. A kind of Radar University grew up, in which J. A. RADCLIFFE, of Cambridge, and DR. L. HUXLEY, of Nottingham, played a great part. There was G. W. DUMMER, whose fertile brain devised synthetic Radar trainers, the use of which saved the R.A.F. £50,000,000 worth of aviation spirit. Then there are DR. J. E. GRIFFITHS, B. BLEANEY and A. H. COOKE, of Oxford, and H. G. HUGHES, whose valve contributions were all indispensable, as were those of J. SAYERS and H. A. H. BOOT, of the Birmingham team. Then again there was the very ingenious work of DR. R. COCKBURN and that sturdiest pillar of Radar, DR. W. B. LEWIS, of Cambridge, who from the depth of his encyclopedic knowledge and the breadth of his interests contributed to every step in the progress of Radar.

Finally, I should mention the work of the Radio Board and its two principal committees, many of whose members are on the platform with me to-day, the Radio Production Executive, and the Signals organisations of the three Services, who, working together with the scientists as one great team, enabled these discoveries to be brought against the enemy to such good purpose.

No list of names could ever be completed. I have done no more than mention some of those whose names must for ever be inseparably linked with Radar, and even them I have mentioned only in relation to one or two highlights of their continuous service to Radar.

The debt which we, and I venture to say the whole civilised world, owe to these men is one which we can never repay. I, for my part, can pay them no higher tribute than by quoting to you the famous verses of Ecclesiasticus:

"Let us now praise famous men. . . . There be of them that have left a name behind them, that their praises might be reported. And some there be which have no memorial. But . . . their glory shall not be blotted out . . . their name liveth for ever more. The people will tell of their wisdom, and the congregation will show forth their praise."

I. F. F.

AN I.F.F. unit can be briefly described as being a transmitter-receiver device installed in friendly aircraft whose purpose is to reply to the interrogation of the friendly Radar station. This it does by automatically responding to small transmitted signals and returning a much stronger coded signal at the same frequency. This coding is readily changeable. It is possible, therefore, by prior arrangement to indicate that the aircraft is friendly, belongs to a certain operational command, or the type of aircraft. The frequency band covered by the I.F.F. is similar to that covered by the stations engaged in the interrogation. In addition, an aircraft fitted with I.F.F. equipment can act as a beacon control for other aircraft by replying to their interrogation. In an emergency the I.F.F. can transmit a coded signal indicating distress. Provision is made for rendering the purpose of the equipment unrecognisable and unusable in the event of it falling into enemy hands. This is by the incorporation of a detonator in the unit which can be fired by pressing buttons or automatically by an impact switch in the event of a crash. The detonator is removable and can be taken out in the case of maintenance, etc.

I.F.F. has had an interesting operational career. When our bombers first carried it over enemy defences it was the cause of surprise and delight to our pilots and bewilderment and consternation to the enemy. The German searchlights were Radar controlled, which was by no means pleasant for our pilots until, when I.F.F. was fitted, it was found that the transmission from the I.F.F. units upset their Radar searchlight system to the extent of switching off the beams. This caused us much amusement until the enemy devised a means of stopping it.

I.F.F. ("Identification Friend or Foe") equipment was conceived by Air Ministry research staff and entrusted to Ferranti Ltd. to develop and produce.

German Views on British Radar

EVIDENCE that the German High Command acknowledged the crushing superiority of British scientific achievement in Radar is provided by a captured German document. This document, issued to high-ranking German officers and scientists in 1943, though couched in the usual German turgid style, makes no effort to disguise past failures in countering British Radar operations and the intensive efforts made to overcome our superiority. It begins with a tribute to British science which, emanating from official sources in Germany, may justly be described as handsome:

"The great superiority thus shown by the enemy in location and recognition service, together with the depreciation of our own warning service from which it still suffers, have eliminated the element of surprise in U- and E-boat warfare and in mining operations by aircraft in enemy waters, besides prejudicing the full utilisation of our own location and enabling the enemy to adopt a tactical method superior to ours by means of his own radio recognition service."

The document acknowledges the failure of makeshift methods of development by which Germany sought to overcome our lead, and their hurried experimental work.

"The development work, mostly very praiseworthy, carried out by Communications Research Command, was often sent straight to the front to save time, without undergoing an operational test by Communications Testing Command. Many obvious results since obtained have shown this to be wrong."

This section of the document concludes with a positive dirge about German difficulties—difficulties which, it may be added, were solved by British scientists as often as they occurred:

"The manufacture of spare parts and the production of descriptions of sets, instructions for use, and manuals could not be achieved to anything approaching the extent required.

"There were at first no properly trained personnel for fitting and repairs. Often after gaining sufficient experience these were drafted into the Army. Mistakes in fitting and repairs, affecting naval forces and U-boats in particular, were the result."

Another significant passage gives by inference an engaging picture of disruption behind the scenes. It is obvious that towards the end hard things were said about the German Radar arm in view of the outright superiority which Britain had established in the field and the apparent impossibility of overtaking her:

"All officers, ratings, civil servants, employees and workmen who have worked in the surface Radar service up to now must have seen from the way it developed that the Heads of the Navy were following events with an unusually critical eye. In view of this critical attitude, owing to the difficulty of realising the whole extent of the work and the constant lack of prerequisites for the successful development, it was not always possible for those not immediately responsible for these things to observe the necessary moderation in their appreciation of the facts. The increasing obvious superiority of the Anglo-Saxon opponent gave rise to sharper criticism, the substance of which was salutary in the long run, in that it thoroughly exposed the dangers of our own inferiority."

—From an official document issued by M.O.I.

A New Calibrated Oscillograph

With Calibrated and Constant Time Base Velocity for the Direct Measurement of Frequency employing a "Signal Converter" as the Time Base Generator

By P. NAGY, Dipl. Eng.*

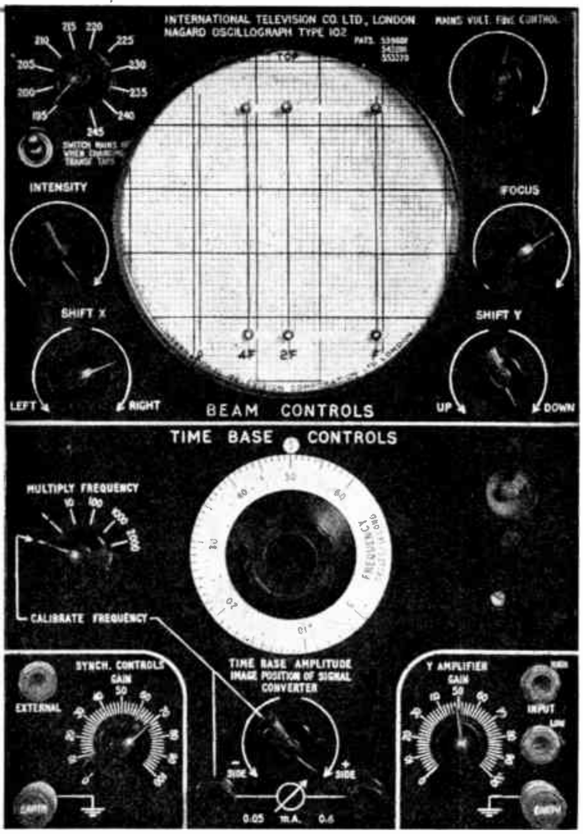


Fig. 3. View of front panel of oscillograph, showing calibrated dial.

1. Introduction

THE cathode-ray oscillograph is, in many respects, a measuring device superior to conventional meters; its input impedance can be made very high; it will register not only R.M.S. and peak values, but give a complete picture of the changes during the whole period of recurrent and non-recurrent phenomena. There is no real reason why it should not be made to register absolute quantities with the same accuracy as other conventional meters.

In the oscillograph described an effort has been made to measure frequency accurately, and to do this employing simple means only.

The usual method adopted for the measurement of the repetition-rate (frequency) of electrical phenomena is a comparative one. The unknown frequency is compared with a known standard—for example, the known frequency is applied to the X-deflection plates of a C.R. tube and the unknown to the Y-plates; by continuously changing the known frequency a stationary Lissajous' pattern appears on the screen of the C.R. tube, whence the relation of the unknown to the known frequency may be determined, or the known frequency may be applied to the grid of the C.R. tube, thus "marking" the time base. Whichever method is employed a continuously variable calibrated signal generator is required.

The accuracy of the frequency determination is the same as the accuracy of the signal generator. A good class heterodyne or C.R. oscillator or a radio frequency signal generator is accurate to ± 1 or 2 per cent.

The alternative solution is the calibration of the time base velocity. When the time required for the spot to travel a predetermined distance on the C.R. tube screen is known, the frequency of the signal under examination may be read off direct on a calibrated transparent screen attached to the C.R. tube.

This latter method is employed in the oscillograph here described. The circuit and some factors affecting the accuracy of calibration and reading are outlined.

2. The Time Base Valve: The Signal Converter

The time base of the oscillograph is generated by a single hard valve, the "signal converter."† It is a deflection modulated cathode-ray valve which is capable of converting an arbitrary signal into its own time base. The operation of the converter is explained with the aid of the circuit of Fig. 1. By an electron optical system (G, A_1, A_2) the image of the elongated cathode K is sharply focused at the output electrode XY. By means of secondary electron emission and the auxiliary grids G_1 and G_2, the output electrode is divided into two parts, the "positive side" Y and the "negative side" X. When the image falls on the negative side, the output load C is charged in a negative sense by the beam current. The time base output potential V after time T is

$$V = \frac{i_x T}{C}$$

where i_x is the charging current of the negative side ($i_x \simeq$ beam current). When the image falls on the positive side, a large number of secondary electrons is released from the surface Y and collected by G_2, thus charging C in a positive sense.

When an input signal is placed on the deflection plate P_1 it is converted into a linear time base output potential across C, automatically synchronised with the input. Thus a part of one period of an arbitrary signal can be investigated on the screen of the oscillograph. C may represent the X-plates of the C.R. tube. This mode of operation may be called "pure signal conversion."

To be able to observe several periods of a signal, the converter is used in a self-generator circuit by employing the resistors R_1 and R_2 and the condenser C_2. When the

* International Television Corp., Ltd.

† A comprehensive account of the signal converter may be found in the *Wireless Engineer*, June, 1943 Vol. XX, No. 237 pp. 273-299.

image of the converter is deflected from one side to the other of the output electrode, the current collected by the screen G_2 changes and so develops a transient signal across R_1 which is fed via C_2 to the deflection plate P_2 in a regenerative sense. With the aid of R_2 through which the signal leaks away, time base oscillations are generated.

The output electrode current as a function of the deflection potential of the plate P_2 is given in Fig. 2; in the *constant current* region x the scan of the time base is produced and the image falls wholly on X; in the sloping part xy the image falls partly on X and partly on Y: in the region y the image falls wholly on the positive side Y and produces the fly-back of the time base. When the image is biased within the slope xy the signal converter will oscillate.

3. The Converter Circuit and Time Base Controls employed in the Oscillograph

After time T the time base output potential $V = i_x T/C$. When the output load C is known and i_x is measured, the scanning velocity of the oscillograph V/T is defined. For some predetermined time base output potential V, the oscillograph may be calibrated direct in frequency $1/T = f$.

The main frequency control (large centre dial on the oscillograph panel, *see* Fig. 3) is calibrated in cycles per second, from 5 to 60 c/s. This control alters the variable resistance R_3, changing the bias of the grid G and thus the beam current (*i.e.*, i_x when the image falls on the negative side X of the output electrode).

It is convenient to make i_x and the number of cycles per second correspond. For example:

5 c/s. i_x = 0.05 mA
30 c/s. i_x = 0.30 mA
60 c/s. i_x = 0.60 mA

Then the calibration of the main frequency dial can be checked with ease with the aid of a milliammeter connected to the output electrode of the converter (by placing the "multiply frequency" switch into the "calibrate" position. This is the main reason why i_x values between 0.05 and 0.6 mA are employed. Low charging currents of the order of 0.05 mA can be safely employed using the signal converter. The two limiting points of the $i_x - V_G$ characteristic (Fig. 4) are set with the aid of the variable resistance controls R_4 and R_5.

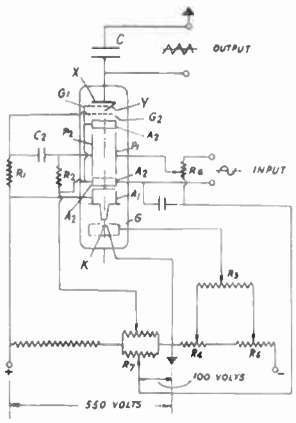


Fig. 1. Schematic circuit of the signal converter as a time base generator.

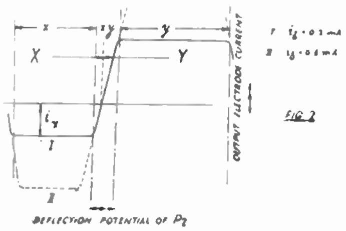


Fig. 2. Output-deflection characteristic of signal converter in circuit conditions of Fig. 1.

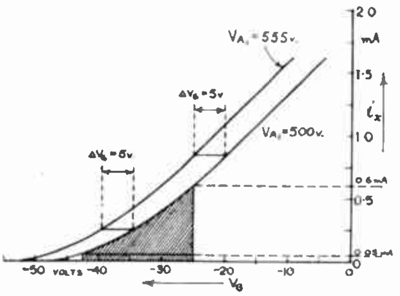


Fig. 4. "Negative" output electrode current characteristics as function of grid bias for different first anode potentials.

To calibrate the main frequency control R_3 any two points, one at the lower and one at the higher end of the characteristic, may be adjusted, *e.g.*:

15 c/s. i_x = 0.15 mA
50 c/s. i_x = 0.50 mA

The value of the output load C is so selected as to give a convenient datum deflection (V) on the C.R. tube screen. The values which have been selected for i_x and T give $i_x T$ = 0.01 milliamp/sec. = constant; then C = 0.05 microfarad gives V = 200 volts, which corresponds to the datum deflection of 3 in. approximately on a tube of 5.25 in. diameter.

In order to produce satisfactory time base oscillations the obvious solution is to couple with the spindle of R_3 two variable resistors R_4 and R_5*. In the oscillograph two 10-pole switches are employed with a chain of small fixed resistors (0.1 watt dissipation).

The frequency reading of the main dial (R_3) is true when the "multiply frequency" control (two 6-pole switches on common spindle) is in the 1 position and so the output load C equals 0.05 microfarad. By placing this control in the 10, 100, 1,000 and 2,000 positions respectively, different output condensers (C = 5,000 pF, = 500 pF, = 50 pF, = 25 pF) and coupling condensers C_2 are switched into the circuit, thereby extending the calibration from 5 to 120,000 c/s.

To lock the time base a fraction of the useful signal is fed to the deflection plate P_1. The calibrated "synch. gain" control attenuates the amplitude of this signal by altering the potentiometer R_6 (*see* Figs. 1 and 3). The synch. signal itself is fed to P_1 via R_6 either from the Y amplifier or externally, by applying the input signal to the terminals provided.

An increase in the amplitude of the synch. signal tends to reduce the amplitude of the time base. As the synch. signal amplitude is increased, the locking is always tighter and the amplitude of the time base is less. If the synch. signal amplitude is increased sufficiently the self-generator action is swamped, and "pure" signal converter action results.

The changes of the time base amplitude due to varying R_7 or R_6 do not affect the constancy of the time base velocity.

The fly-back of the time base is blacked out by connecting the collector screen of the converter via a condenser to the grid of the C.R. tube. The scan to fly-back ratio is constant for all time base velocities.

4. Measurement of Frequency

The C.R. tube is provided with a transparent calibrated screen, having three parallel riders and a red zero line. The position of the riders is indicated by the letters $4F$, $2F$ and F, corresponding to the time

* In the September and October, 1943, issues of *The Wireless Engineer* a detailed account is given of the oscillograph and the theory of the signal converter as a time base generator.

base output potential $V/4$, $V/2$ and V (V = 200 volts). When the observed signal shows n complete cycles between the red zero line and the F rider, then the frequency of the signal is n times the frequency indicated by the main dial and the frequency multiplier. If only that number of cycles is counted which lies between the red zero line and the $4F$ or $2F$ rider—as may be more convenient—then the number of cycles counted must, naturally, be multiplied by 4 or 2 respectively. The start of the scan should be adjusted close to the red zero line.

The accuracy of frequency measurement is within 1 per cent.

5. Elimination of the Influence of Mains Variations on the Accuracy of Frequency Measurement

In order to measure accurately, it is essential to eliminate the effect of mains voltage variations. These would alter the beam current of the signal converter and the deflection sensitivity of the C.R. tube.

Observations extending over a considerable period have shown that two distinct types of mains disturbance have to be dealt with, namely: sudden surges due to switching on and off of nearby machinery resulting in small deviations of the mains potential, and a slow change of much greater magnitude (of the order of 5, or occasionally even 10, per cent.) due to the periodic daily decreasing and increasing demand.

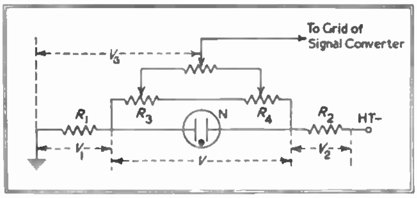


Fig. 5. Correcting circuit for mains disturbances

The former type of disturbance changes only i_x; its effect on the deflection sensitivity of the C.R. tube and other parts of the circuit is negligible, being within the calibration accuracy of the oscillograph. Unless corrected, the frequency mains surges would considerably affect the time base velocity, the steadiness of the time base and so the synchronisation.

The correcting circuit—shown in Fig. 5—is simple, consisting of two resistors R_1 and R_2 (dissipation 0.1 watt) and a small voltage stabiliser N (95 volts, consumption 4 mA). The circuit is based on the constancy of the amplification factor A of the converter gun system.

For some fixed i_x value the amplification factor is an absolute constant for all practical values of the first anode potential*; changes of heater voltage do not affect it. It is also substantially constant for i_x values between 0.05 and 0.6 mA†.

In Fig. 4:

$$A \simeq \frac{\Delta VA_1}{\Delta V_G} = \frac{55 \text{ volts}}{5 \text{ volts}} = 11$$

From the aforesaid it follows that if the mains potential alters, say, 10 per cent., the grid potential V_G must be shifted 5 volts relative to earth potential for all values of i_x; this is accomplished if the range of potentials stabilised by N is shifted *in toto* by 5 volts. Then the constancy of i_x is not affected by mains variations.

The slow mains voltage changes are checked and controlled with the aid of an electron beam visual indicator, sensitive to less than 0.25 per cent. mains variation. The correct input to the mains transformer for standard mains voltages is applied by connecting the appropriate tap on the transformer primary (5-volt steps from 195 to 245 volts are provided) and by adjusting the "mains voltage fine control" variable resistance. When the visual indicator is uniformly illuminated, the adjustment of the mains potential is correct.

* Disregarding the effect of space charge close to the cathode, the amplification factor is determined by the ratio of cathode-grid and cathode-first anode capacities.

† A decrease of the amplification factor occurs only at very low i_x values, *e.g.*, at i_x = 0.005 mA the decrease of A is of the order of 5 per cent.

A Plan for Better Radio Listening

New Wavelength Scheme Proposed by the Radio Industry

A new wavelength scheme which would enable every European nation's broadcasting service to be appreciably improved and which would benefit all listeners is proposed by the Technical Committee of the British Radio Equipment Manufacturers' Association

THE plan advocates a new arrangement of wavelengths and transmitting powers based on engineering principles which would give listeners in this country and all over Europe increased quality and quantity of listening; greater freedom of choice of programmes; decreased interference; better opportunities of listening to other countries.

It is based on the scientific fact that the longer the wavelength of a broadcasting station, the greater the area over which it can give a reliable service. Since stations at the lower end of the medium waveband are thus naturally restricted in their useful range, it is better that they should be used for local or regional services only, leaving the upper part of the medium band and the whole of the long waveband for stations which would have a nation-wide range.

This is precisely what the new plan provides. Shifting the "local" services of all countries to the lower end of the medium waveband, and slightly extending downwards the present long waveband, would provide enough channels to give every country in Europe (and every large language group in the case of dual-language countries) *two* reliable national programmes. At the same time, it would allow the present 9-kilocycle separation between stations to be increased to 11 kilocycles, thus reducing very considerably the interference between stations and providing a much needed opportunity for improving the musical quality both in transmission and reception.

Under the plan, the former conception of "long" and "medium" wavebands would be replaced by a "national" waveband extending from 2,000 to 259 metres (150 to 1,157 kilocycles) and a "regional" waveband from 259 to 192 metres (1,157 to 1,560 kilocycles). Within these wavelengths it is claimed that every nation in Europe can be given an adequate (and in most cases an improved) broadcasting service.

The sponsors of the report make it clear that their proposed solution of the problem is by no means a hard and fast one, and that it offers considerable elasticity in the wavelength allocation. They commend it to the earnest consideration of those who are able, in the proper places, to influence the future development of broadcasting, in the belief that the present phase in Europe holds a valuable opportunity and—in the view of British radio engineers—an obligation to correct past mistakes.

Television in France

By
P. HÉMARDINQUER*

A note on the position of television in France during the war, and post-war prospects.

(Translated from the French)

AT the outbreak of war in September, 1939, the French Broadcasting Service was undertaking regular test transmissions of television, including direct studio programmes and films. The wavelength of the transmitter was 6.52 m. (46 Mc/s.), sound being radiated on a wavelength of 7.14 m. (42 Mc/s.).

The picture definition varied between 440 and 455 lines, interlaced, 50 frames per second. The aspect ratio was 5 : 4.

At that time several manufacturers were putting out regular test transmissions under slightly different conditions. La Cie des Compteurs (M. Barthelémy) used 450 lines, the B.T.-H. Company (under Marconi licence) had adopted 455 lines, and la Cie Grammont 441 lines (German standard).

Television during the Occupation

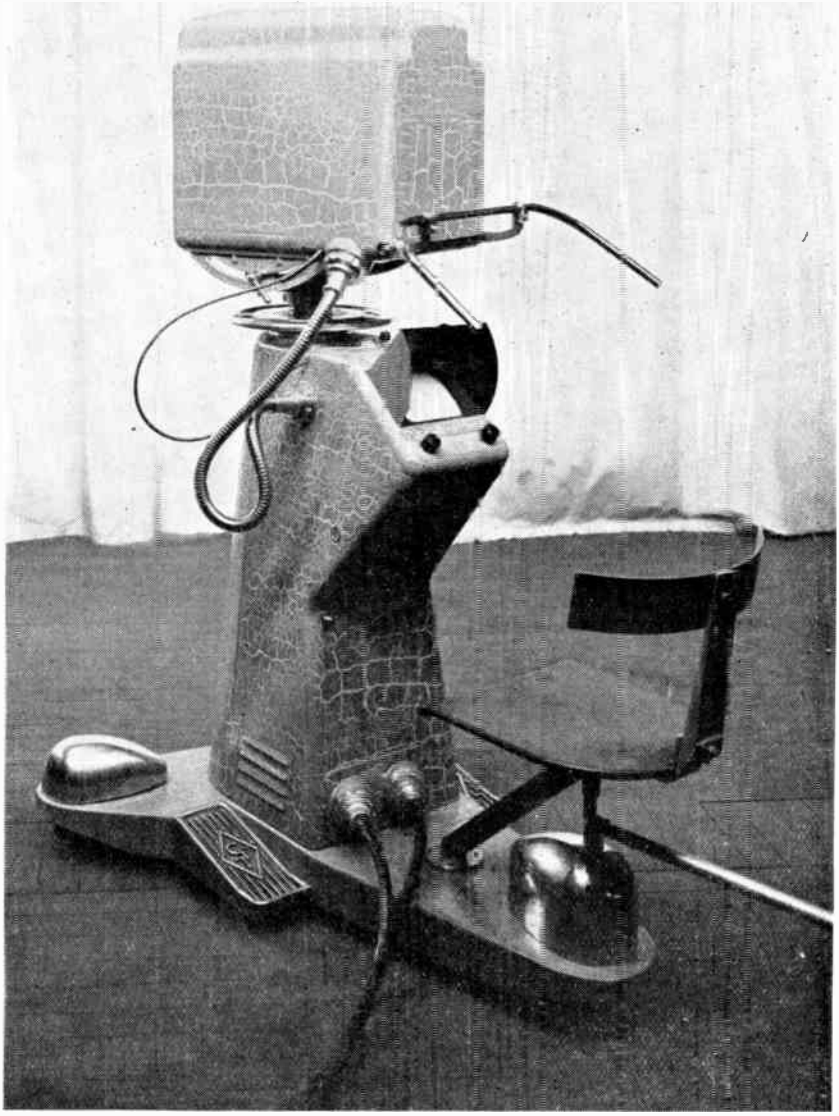
The declaration of war interrupted the experimental transmissions, which were only resumed in July, 1940, under German control. In 1943 the Vichy Government's Broadcasting Administration arranged with the German authorities to undertake television transmission in Paris on the German standard of 441 lines. The arrangements were in the hands of German and French technicians.

The original Eiffel Tower transmitter was used with some modifications, but the studios, which were formerly at the Ministry of Posts and Telegraphs, were replaced by new installations in the neighbourhood of "Magic City." The transmitting equipment was of German manufacture and supplied by A.E.G. and Telefunken, chiefly for Telecine.

The transmission was poor, and the synchronising varied considerably during the course of the transmission. The French public, both on moral and material grounds, did not take much interest in programmes under enemy control, but nevertheless this did allow certain manufacturers to develop receivers and undertake useful research.

On the liberation of Paris, the Germans dismantled and took away all the studio camera equipment but, doubtless from lack of time, left the Telecine transmitters. In general, the studio is almost intact. On the other hand, the Eiffel Tower transmitter was almost completely destroyed before the Germans left: the fragile apparatus was smashed, machines and cooling plant broken and the oil-filled transformers were punctured by bullets. Fortunately, they did not have time to blow up the aerial and feeder installation, although an explosive charge had been prepared for the purpose.

Now reconstruction has to be undertaken in common with the reconstruction of all the destroyed broadcasting stations. The Director



French television pick-up camera with electronic viewfinder.

* Consulting Engineer, Grenoble.

of French Broadcasting earnestly desires to see French television take a leading place in the world and every effort is being made to reach this goal. The installation of a large experimental television centre in Paris was commenced in 1944, but transmission so far has not been undertaken for military reasons.

At the time of writing it is certain that transmission will be made on the 1939 standard, *i.e.*, 441-455 lines, 50 frames per second interlaced. However, the results obtained in various research laboratories, and in particular by M. Barthelémy, suggest that the existing standard can be ultimately replaced by a definition of the order of 1,000 lines. The possible delay in putting this new system into operation is given in some quarters as two years. Certainly this would seem to be the minimum time having regard to the enormous industrial difficulties in France at the present moment.

The receivers acquired for the present television standard will not be suitable for the very high definition transmissions, and under the circumstances it does not seem reasonable to ask television viewers to acquire receivers at a high price which will only be serviceable for a short time before becoming valueless.

It has been proposed to make available receivers which will not be sold, but hired, at a cost which will vary according to the length of use. This seems to be a satisfactory and practical solution, which should encourage a satisfactory number of viewers. The present television standards are capable of producing excellent results and they allow constructors to study transmission problems, besides enabling viewers to form an opinion of the possibilities of television reception even under the present provisional conditions.

It is probable that the experimental transmission will be more or less limited to the Paris area. On the other hand, as soon as the new standard is introduced, the whole country will be covered if possible. The development of such a network will be gradual and will commence with the equipment of urban districts where the population density is greatest. The first programmes are planned to cover the towns of Lille, Lyons, Marseilles and Bordeaux.

The interlinking of the different stations will be accomplished by radio relay as adopted elsewhere. This seems to be the most practical method for the transmission of frequency bands of 10 to 20 Mc/s.

At the commencement, transmissions will be given three days a week with two programmes a day of 1½ hours' duration.

During the war, the research laboratories, prevented from pursuing work of industrial importance, devoted their time to technical work on a variety of subjects. This work was first of all concerned with the quality of the picture. Experiments have shown, in principle, that the ultimate definition is limited, not by electronic factors, but by the optical viewing conditions and the photographic characteristics of the film transmitted.

M. Barthelémy has already developed a transmitter and receiver capable of giving pictures with a definition greater than 1,000 lines corresponding to a frequency band of 15 Mc/s.

The investigation of very high definition pictures would give few results of interest if the pictures were affected by optical defects, such as distortion and irregularity of brightness and, above all, if they were not obsolutely stable. A stable picture of minimum definition is definitely preferable to a higher definition picture which is continually failing due to some fault in the synchronism.

The developments in transmission, particularly in the utilisation of steep-fronted waves, have contributed largely to the stability of the picture.

A pick-up tube, using slow electrons, termed the Isoscope, has been developed by M. Barthelémy and avoids the disadvantages of the Iconoscope besides permitting direct modulation of the carrier by light.

Reverting to an earlier idea, which was never put into practice with success, French inventors, such as M. P. Toulon, have suggested the use of large multi-cellular screens with the object of avoiding the use of projection tubes. Improvements in existing equipment have also been made, such as the production of cameras with electronic viewfinders, of which an example is shown in the figure.

With the great interest taken in the future of high definition, the possibilities of medium (450-line) definition should not be overlooked and the transmission of direct scenes and films can be studied with advantage.

Such is the general position of television in France at the present time and it is hoped to describe some of the more interesting research work carried out during the war in a later article.

Leakage of Water through Tungsten Seals

By

A. L Chilcot, M.B.E., B.Sc., A.M.I.E.E.

(Electronics Laboratory, Ferranti Ltd.)

It has recently been found that small tungsten seals in a hard borosilicate glass, which are completely vacuum tight under normal conditions, are permeable to water when immersed in wet steam or in hot or cold water. The effect was discovered in the course of production of a small type of cold-cathode tube filled with gas at low pressure with .025 in. diameter tungsten seals, the length of the seals being about .125 in. The type of tube concerned is very sensitive to water vapour impurity and the effects of water vapour are quite distinct from those of air. Each tube has three seals and 80 per cent. of the considerable number of tubes tested have shown the effect in varying degree. Both drawn tungsten wire and swaged tungsten rod have been tested and give similar results. In extreme cases the effect is detectable after a few hours' immersion; the slowest take several days.

No experiments have been undertaken to determine the mechanism of the water leakage, but there is some evidence that water in the liquid state (due either to water condensed from steam or actual immersion in liquid water) is necessary for the leakage to occur, and there is good evidence that the leakage occurs faster in water than in steam. The leakage is not a plain diffusion effect, because the seals are not permeable to hydrogen.

Longer seals than the one described have not been tested, but it is reasonable to assume that the rate of leakage is reduced by increasing the length of seal and possibly prevented altogether if the seals are long enough. Gettered tubes are likely to be less sensitive in showing water leakage, because of the clean up action of the getter.

—*Science Forum*, March, 1945, page 10.

A Video Frequency Oscillator

By C. H. Banthorpe

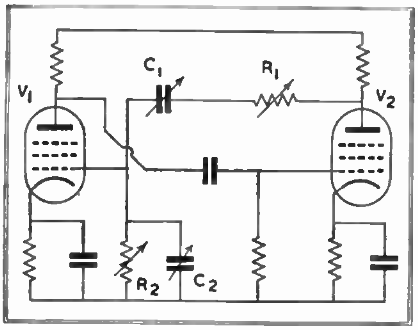


Fig. 1.

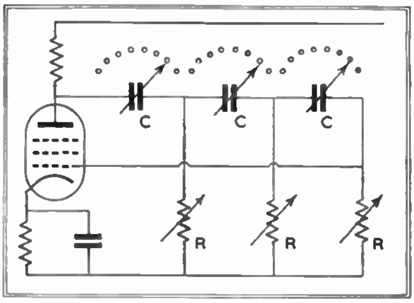


Fig. 2.

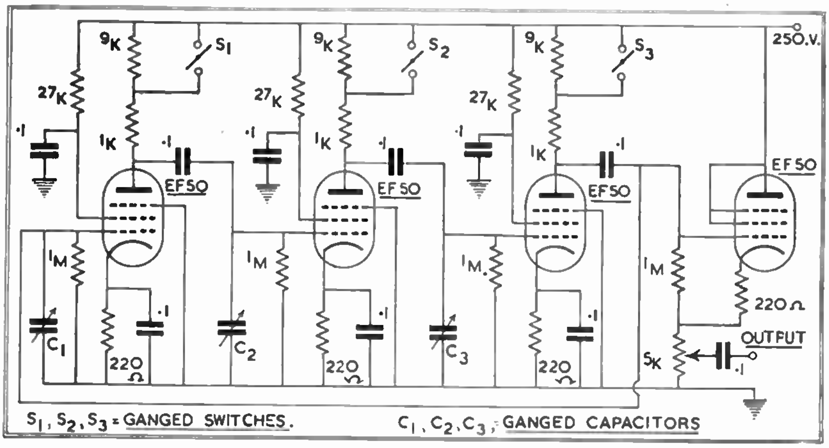


Fig. 3.

THERE are many uses for an oscillator covering up to approximately 5 Mc/s. and in general such oscillators have been constructed on the beat frequency oscillator principle, which is relatively difficult to construct to give a good output waveform and maintain constancy of calibration. The phase shift oscillator principle is well known and several commercial models have been produced which are reasonably cheap, maintain calibration accuracy for long periods and give a good output waveform, but they do not usually generate frequencies above the upper audio frequencies, say, 20 kc/s. The phase shift oscillator is of basically two types: (a) the zero phase shift and (b) the 180° phase shift oscillator. Fig. 1 shows the fundamental zero phase shift oscillator. The condition for oscillation is that the voltage at the anode of V_2 should be in phase with the voltage at the grid of V_1, and sufficiently large to produce a gain from the grid of V_1, through V_1, V_2, and the phase shift network R_1C_1, R_2C_2, back to the grid of V_1. If the current through R_1C_1 is advanced 45° from the voltage at the anode of V_2, and the voltage across R_2C_2 is also lagging the current, then the voltage at the grid of V_1 will be in phase with the anode of V_2. This occurs when

$$R_1 = \frac{1}{\omega C_1} = R_2 = \frac{1}{\omega C_2}$$

One of the disadvantages of this circuit is that C_1 has both sides above earth potential, and a normal 2-gang variable capacitor, as used in broadcast sets, cannot be used unless the frame is insulated from earth. The waveform is generally not good unless some sort of amplitude control is included.

The 180° phase shift oscillator generally takes the form of Fig. 2 and has the great advantage that a normal 3- or 4-gang capacitor may be used. Alternatively a 3-gang potentiometer may be used as the continuously variable element, while the capacitors are switched in steps. This has the advantage that generally a much greater variation of frequency may be made on each band but variable resistors are not nearly so stable as variable capacitors, and the tracking does not approach that of even a cheap tuning gang capacitor. For a 3-stage oscillator it may be shown that the frequency of oscillation is equal to:

$$\frac{1}{\sqrt{6}\,.\,2\pi RC}$$

and the gain must not be less than 29. As the frequency is increased the values of resistors and capacitors decrease until a limit is reached when stray capacities only are used.

Some of the limitations of the normal phase shift oscillator may be overcome by the circuit shown in Fig. 3 where the gain is spread over 3 valves. For a phase shift of 60° per valve the gain must not be less than 2 and assuming a valve with a slope of 8 mA/V, say an EF50, the anode load must be not less than 250 ohms. Assuming 15 *pF* input capacity of each valve + 5 *pF* output capacity + 30 *pF* the minimum of the gang capacitor + strays, a total of, say, 50 *pF*, this gives the highest frequency as approximately 22 Mc/s.

If the upper frequency desired is 5 Mc/s. the anode loads may be put up to 1 KΩ, and the frequency coverage for a typical 3-gang tuning capacitor will be 400 kc/s.–5 Mc/s. approx., and if two ranges are provided by switching the anode loads, the ranges may be 40 kc/s.–500 kc/s. and 400 kc/s.–5 Mc/s.

This total range is extremely useful and serves for practically all video amplifier measurements. Moreover, the output is practically constant throughout this range, but is adjustable from 0 to 10 volts peak-to-peak.

The complete circuit shows the addition of a cathode follower to provide a low impedance output and serve as a buffer between the oscillator and the output.

Acknowledgments

The author would like to express his gratitude to his colleagues, Mr. G. W. G. Court and Mr. J. Dean, for their help and interest in the above note.

NOTES FROM THE INDUSTRY

Radio Makers' Switch to Peace Production

Trade Mark Sets in Autumn

A plan for the partial changeover of radio industry production from war to peace equipment has now had Government approval and makers have new programmes in hand, announces an official of the Radio Industry Council. The first new sets are likely to be available in the autumn, although initially supplies will be very limited since radio factories are still engaged largely upon war equipment required for the Far East. Not until well into 1946 will there be a possibility of making any substantial inroad into the large public requirements for new radio receivers.

The first post-war sets will be very similar to models in the immediate pre-war ranges, which had reached a high standard of performance; refinements of production introduced during war-time will add to reliability and general efficiency. The new models will be individual designs backed by the radio manufacturers' trade marks so well known before the war.

Labour and material costs are likely to make the prices of the new sets considerably higher than the immediate pre-war models; and, like other household necessities, purchase tax has to be added.

Arrangements with the Board of Trade will result, however, in a large percentage of the production being in sets at a price of £15 or under, exclusive of purchase tax.

The Post-War Amateur Radio Market

Manufacturers and retailers of radio components for the post-war market will be particularly interested in a report issued by the Radio Society of Great Britain giving their recommendations on the types of component which will be in demand by the amateur radio enthusiast when experimental licences are reissued.

During the war the membership of the R.S.G.B. has increased to nearly 10,000 and this number entitles their recommendations to be given serious attention. Copies of the report will be sent to interested manufacturers on request to the Secretary, R.S.G.B., New Ruskin House, Little Russell Street, W.C.1.

Neat Push-Button Switch

The attached photograph shows the Brookhirst block-type push-button, suitable for flush mounting and surface mounting respectively. The internal assembly of the switch is ingenious and incorporates self-cleaning contacts, the action of which may be watched through mica inspection windows.

The fixed contacts are not attached to the housing in any way, but are easy fits in registration recesses. This facilitates the attachment of small wiring connexions and there is no manœuvring of screwdrivers into almost inaccessible places.

The design can be used in three ways:

(a) For making a circuit;
(b) For breaking a circuit;
(c) For breaking one circuit and making another.

An informative leaflet is available on request from Brookhirst Switchgear, Ltd., Chester.

S.I.M.A. New Chairman

At a recent Council meeting of the Scientific Instrument Manufacturers' Association, which comprises 75 firms with 60,000 employees, Mr. J. E. C. Bailey, chairman and managing director of Baird & Tatlock, Ltd., was elected president for the ensuing year in place of Mr. F. Wakeham.

Co-Ax Cables

A new leaflet issued by Transradio, Ltd., describes the method of obtaining air insulation in their Co-Ax cables by means of hollow insulators surrounding the conductor. The use of air dielectric gives lower loss and greater uniformity with lighter weight. Cables can be supplied to almost any electrical or mechanical specification.

—*Transradio, Ltd.*, 16 The High, Beaconsfield.

New Philips Works

Soon in Production in Scotland

Philips Lamps, Ltd., are to open a factory in Hamilton, Lanarkshire and it is hoped that production will commence before the end of this year. The factory, which is a large one, is almost completed, and it will produce radio receivers and components.

The factory is specially built for radio manufacture, which is a new industry for Hamilton. A new company, Philips Hamilton Works, Ltd. is being formed.

W. J. Harris, who for many years has been responsible for the activities of the Philips company in Scotland in a statement to the Press, said that the Hamilton factory would be the third large manufacturing unit to be developed by the company in this country. The two others are in Mitcham and Blackburn.

The new factory, which occupies 13 acres, will employ 5,000 operatives.

Name Change

The stockholders of the Westinghouse Electric and Manufacturing Company recently voted a change in the corporate name for simplicity and brevity.

Henceforth the company will be known as Westinghouse Electric Corporation. No other change in company structure was made at the annual meeting.

—*Radio News*, July, 1945, p. 34 (supplement).

Television Aerials

A catalogue issued by Messrs. Aerialite, Ltd., of Castle Works, Stalybridge, deals with types of television dipoles and reflectors suitable for mounting on chimney stacks.

The company recommend lashing the brackets to the brickwork by means of the special lashing cord provided as this saves fitting time and simplifies the work of erecting. The booklet gives much useful information on the elimination of ghosts and the performance of aerials and reflectors. A similar catalogue describes the "Mastatic" Noisefree Aerial System with notes on its performance and erection.

SEPTEMBER 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.*

Institute of Physics
Electronics Group

Date: September 14. Time: 5.15 p.m.

Held at:

The Rooms of the Royal Society, Burlington House, London, W.1.

Annual General Meeting followed by

Lecture:

"Electronic Conditions in the Sun and Stars."

By:

Dr. D. S. Evans (The University Observatory, Oxford).

Group Secretary:

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

The Television Society *

Date: September 25. Time: 5.45 p.m.

Held at:

The Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Informal Meeting and Reunion. Tea will be provided.

Note.—Members wishing to bring friends are asked to notify the Lecture Secretary as soon as possible.

Lecture Secretary: G. Parr, 43 Shoe Lane, E.C.4.

Institution of Electronics
North-West Branch

Date: September 21. Time: 6.30 p.m.

Held at:

The Reynolds Hall, College of Technology, Manchester.

Lecture:

"The Theory, Design and Application of Magnetron Valves."

By:

R. G. B. Gwyer, M.A.

Hon. Secretary:

L. F. Berry, 105 Birch Avenue, Chadderton, Lancs.

The Association for Scientific Photography*

Date: September 27. Time: 6.30 p.m.

Held at:

Alliance Hall, Westminster, London, W.1.

Lecture:

"Recording Engineering and Other Work by Stereoscopic Photography."

By:

R. Peel.

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

NOTICE

Admission of Non-Members to Meetings of the Institution Electrical Engineers

In September, 1943, the Council instituted a scheme for making the technical meetings of the Institution accessible to those who may be interested in the proceedings but who may consider that their technical experience and educational attainments do not suffice to admit them to any form of Institution membership.

The Council have recently reviewed the working of the scheme during the past two Sessions and are satisfied that it has performed a useful function. They have decided that it should be continued for the coming Session, and have accordingly ordered that a person in the category outlined above shall be provided by the Secretary with an application form, on the completion of which and on payment of a fee of 10s. to cover administrative costs, he may receive notices of meetings and an invitation card which will serve as a title of admission to the technical meetings of the Institution to be held during the forthcoming Session in London and in the provinces.

The possession of the invitation card will not confer upon the holder any status within the framework of the Institution, nor will he have the right to join in the discussions without special permission from the Chair.

Those interested in this new facility, whether they reside in London or in the provinces, should apply to the Secretary of the Institution for further details and form of application.

CORRESPONDENCE

Properties of Plastics

DEAR SIR,—The need for exactness in all electronic matters impels me, even after so long an interval, to draw attention to three statements in your May issue to which attention has just been directed.

On page 499 of the article "Tropic-proof Radio Apparatus," the author states that methyl methacrylate windows will warp after extensive exposure to humid atmospheres. This is not accurate, as "Perspex" and other types of methyl methacrylate are unaffected by humidity changes.

The second and third occur in the article "Plastics in High-frequency Insulation" (page 516). The statement is made in column 1 that the specific gravity of polystyrene is the lowest of any plastic material. In fact, the specific gravity of polystyrene is 1.05 as compared with that of 0.92 for polythene, which is an excellent moulding material. Finally, in column 3 the author says: "As the temperature is lowered, polythene gradually stiffens and finally breaks on bending at about – 20° C."

It may be of interest to you to know that there are now harder grades of polythene being widely used which do not crack even at – 60° C.

Yours faithfully,
SIDNEY ROGERSON.
Imperial Chemical Industries.

Mr. W. J. Tucker replies :

I am pleased to have the comments of I.C.I. on the material in question and hope to deal with the subject again in a final article, which will be modified accordingly.

Mr. P. I. Smith replies :

Information released since my article was written in June, 1944, gives evidence of the growing usefulness of polythene in electrical engineering; in fact, this thermoplastic has contributed appreciably to the success of Radar.

Polystyrene (Sp. gr. 1.05) has long been considered to be the lightest in weight of all plastics, but it must be now admitted that it has been ousted by polythene (Sp. gr. 0.92). I agree with I.C.I that polythene is an excellent injection moulding material and examples of work in my possession convince me that this material will be even more extensively employed than hitherto.

The statement that polythene gradually stiffens and finally breaks on bending at about – 20° C. is true for some of the softer grades of polythene. Developments have taken place which ensure that this material does not crack even at – 60° C.

Tropic-Proof Components

A Reader's Experience

DEAR SIR,—I have read with very great interest Mr. W. J. Tucker's articles in *Electronic Engineering* entitled "Tropic-proof Radio Apparatus."

From several years' practical experience in Malaya on servicing radio and electronic apparatus I have encountered most of the troubles you have described, but it occurred to me that readers might be interested in a few of my views and experiences in this important branch of the industry.

I think that all export tropical gear intended for industrial or domestic markets should have a Board of Trade Certificate for suitability, as the consumer will hesitate to buy if he knows that the subsequent service costs will be high. Many people do not wish to burden themselves with such a liability, or having been caught once refuse to buy again although the product has since improved in reliability.

My experience with the Chinese consumer is that he likes to invest in a high quality product which will last a lifetime. Of course, the needs of war have improved tropical technique out of recognition and no doubt the domestic product will benefit, but I hope that the standard demanded by the Services will be maintained in our export trade.

Referring to the list of possible causes of breakdown I see no mention of the ravages of insect life on radio sets. The worst culprit in my view is the mason bee. These minute bees build their nests in various nooks and crannies, a very common place being in the loudspeaker gap, resulting in a complete seizure of the coil. I have also known tuning condensers to suffer in the same way. Also they have a decided taste for the insides of 5-amp toggle switches. Cockroaches leave a nasty corrosive deposit which cause the usual cadmium-plated chassis to become a mass of rust in a couple of years if not attended to at frequent intervals. The small house lizard, the "chik chak," sometimes gets itself shorted across H.T. or mains with unpleasant results. When this happens, after some days, if the set is still working, an abominable smell emanates from the receiver. The only cure that has suggested itself to me is to fit wire gauze over the ventilating holes. This certainly is effective, but at the expense of the ventilation. However, I think there is a case for making tropical domestic receivers insect-proof.

The table below shows the most common faults I have found in receivers. The humidity was about 95 per cent., water rapidly appearing from condensation on the outside of a glass of cold water in open air, but the temperature cycle not too great, about 25-30° C. throughout the year. Other pieces of apparatus subject to almost immediate breakdown as soon as unpacked were gramophone motors and pickups, crystal type dissolving, also rotary converters and generator sets.

Of course, a technique was developed in dealing with these problems otherwise business would have been impossible. To give an idea how the market was neglected in Singapore, out of a population of 600,000 in 1939 there were only about 10,000 licences to the best of my belief.

Yours faithfully,
R. C. JOYCE.

Component	*Fault*	*Possible cause*
Paper tubular condensers	Leak or short	Damp
Gain controls	Noisy	Damp or fungus
Audio and speaker transformers	Shorted turns	Damp or electrolytic action
Green spots on I.F.T.s and R.F. coils particularly when the primary is carrying D.C. in spite of wax covering		Damp and electrolytic action
Electrolytic condensers	Drying up	Heat
Loudspeakers	Cone flabby or spider weakened	Damp and fungus
	Coil seized up	Mason bee
Miscellaneous shorts due to ravages of cockroaches, white ants, etc.		
Mains transformers	Shorted turns, etc.	Damp
Bakelite or paxolin components carrying H.T., R.F. or mains suffering from "tracking"		Damp or fungus
Aerial coupling coils	Burnt or charred	Lightning

ABSTRACTS OF ELECTRONIC LITERATURE

INDUSTRY

Electronics in the Handling of Materials

(*B. G. Higgins*)

This article describes variable speed conveyor control, lift levelling or decking and electronic motor control. The conveyor control is accomplished by an electronic control panel with two electrical devices known as selsyns, a selsyn being virtually a small synchronous motor. The levelling of lifts at different floor levels can be obtained, by electronic devices, accurate to plus or minus one-quarter of an inch. The article also shows how electronic control can be applied to D.C. electric motors giving steady speeds over a maximum speed range of 50 to 1.

—*Mech. Hdlg.*, June, 1945, p. 298.*

Hard Surfaces on Steel by Induction Heating

(*J. L. Aston*)

High-frequency induction heating has been frequently applied to the heat treatment of parts during recent years. The rapidity of heating and the small floor space required make this form of heating especially applicable for use in main production shops. The article covers high-frequency generators and supplementary equipment, as well as the applications of surface hardening and the technique of induction hardening.

—*Metgia.*, May, 1945, p. 24.*

Something New in Remote Control

(*T. J. Kauffeld*)

This article discusses a new remote control system comprising an electro-mechanical device by means of which an operator is able to control a motor-driven mechanism at a remote location in such a way that the controlled unit will assume a desired position with extreme accuracy. The system may be divided into four basic types of control: continuously variable control, multi-turn selector, dual control and integrating selector, each of which is treated separately by the author. Lack of specific engineering information is explained to be due to war-time restrictions.

—*Iron and Steel Engr.*, April, 1945, p. 61.*

The Design of Low-Voltage Welding Power Distribution

(*C. A. Adams, J. R. Fetcher, A. C. Johnson*)

This paper is an effort to state clearly, and to present a solution for, the problems encountered in the design of one of the vital constituents of A.C. resistance welding power supply—the low voltage feeder. The scope of the paper is much wider, however, since the determination of design loads from the probability standpoint for the purpose of determining maximum allowable impedance and expected temperature rise is a problem encountered in the design of all equipment common to a number of resistance welding installations.

—*Trans. A.I.E.E.*, December, 1944, p. 1180.*

Design of an Electronic Frequency-Changer

(*C. H. Willis, R. W. Kuenning, E. F. Christensen, B. D. Bedford*)

This paper discusses the circuit arrangement and design features of an electronic frequency-changer station for interchanging power between the Carnegie-Illinois Steel Corporation's 25-cycle system and their 60-cycle system. The power transformers, reactors, tube cubicles and R-C filters are briefly described; the inverter deionisation time, commutation and operation are examined: and the phase-shifting circuits, ignitor circuit and grid circuit are dealt with. Rectifier and inverter faults are briefly considered.

—*Trans. A.I.E.E.*, December, 1944, p. 1070.*

The Use of Glass in High Vacuum Apparatus

(*R. W. Douglas*)

The more important physical properties of glass are summarised and an indication given of their relevance to practical problems. A table of the chemical composition of the glasses used in high-vacuum devices is given and accompanied by a discussion of their viscosity, electrical conductivity, thermal expansion and endurance. Factors playing a major part in determining the behaviour of glass to metal seals are mentioned and the effect on heat treatment on a seal is shown graphically.

—*Jour. Sci. Inst.*, May, 1945, p. 81.

C.R. TUBES

The Image Formation in Cathode-Ray Tubes and the Relation of Fluorescent Spot Size and Final Anode Voltage

(*G. Liebmann*)

A new equivalent-optical system consisting of three lenses to represent the electron optical system of a cathode-ray tube gun is described in this article. The image formation is discussed and it is concluded that the fluorescent spot is an image of the cathode and that its size is almost independent of the anode voltage if lens errors can be disregarded. The new theory is compared critically with earlier theories which led to different predictions, and applications of the new conception to cathode-ray tube design are briefly discussed.

—*Proc. I.R.E.*, June, 1945, p. 381.*

ELECTRON OPTICS

A 100-kV Electron Microscope

(*L. Marton*)

In this paper a transmission type electron microscope with magnetic lenses is described. The electron speed can be varied between 30 ekV and 100 ekV. The magnification of the instrument is produced in three stages. The instrument has improved air locks, hydraulically operated stage movement, and a stage tilting device up to ± 15½°. It is also provided with means for bright and dark field illumination and for conversion into a diffraction camera. Improved electrical circuits provide the necessary stability of the power supplies.

—*Jour. App. Phys.*, March, 1945.*

The Electrical Charging of Electron Diffraction Specimens

(*D. G. Brubaker, M. L. Fuller*)

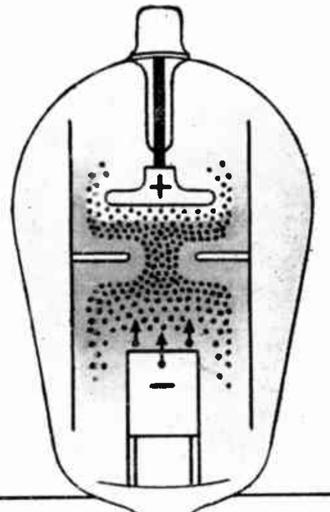
In the use of electron diffraction for the identification of materials by the reflexion method, difficulty is often encountered because the material acquires an electric charge under the influence of the beam which strikes it. This article shows that the magnitude of the charges can be reduced and their effects on the diffraction patterns made negligible by irradiation of the specimens by a beam of 400-V electrons directed perpendicularly to the specimen surface.

—*Jour. App. Phys.*, March 1945, p. 128.*

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

B T-H

RESEARCH



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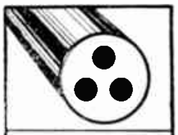

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BOOK REVIEWS

Introduction to Short Wave Therapy

E. Fritsch and M. Schubart. 139 pp., (100 figs. (General Radiological, Ltd., 7s. net.)

This book is a translation of the German text first issued in 1935 with additions by the publishers on Home Office regulations, and rules for operating valve apparatus.

It is intended for technicians and for students preparing for qualifying examinations and covers the whole subject in a thorough manner. After an introductory section on physical principles, there are chapters on technique of generation, output of apparatus, electrodes, and the principles of treatment technique. Approximately half the book is devoted to the treatment of specific diseases, and there is a special section on the short-wave treatment in opthalmology.

The typical illustrations of field lines for different electrodes and electrode positions are particularly good, and the whole book can be said to cover the subject clearly and concisely.

Radio Service Test Gear

W. H. Cazaly. 89 pp., 46 figs. (Pitman & Sons, 6s. net.)

The subject matter of this book appeared originally as a series of articles in the *Wireless World*, and on superficial reading one might wonder whether there were sufficient demand for its issue in book form.

The author states in his prefatory note that he cannot supply constructional details and confines himself to a general discussion of the various pieces of test equipment—Standard Signal Generators, Output Meters, Valve Voltmeters, Valve Testers, etc.

On reading the book carefully, however, it will be seen that the author has taken great pains to deal with the underlying principles of measuring equipment and to explain both why the measurements are necessary and why the apparatus takes the form that it does.

The reader of the book will thus be in a better position to construct and appreciate the use of his own test gear than one who blindly copies a circuit diagram from an article or textbook, even though it is guaranteed lay reader.

The style and illustrations are excellent. G. P.

The Nature of the Atom

G. K. T. Conn. (Blackie & Son, 4s.6d. net.)

This is one of the series: "Blackie's Tracts in Recent Physics," and is particularly apposite to present day reading.

The style is not too popular and is well suited to the engineer who is rusty in his knowledge of atomic physics, as well as the intelligent reader.

The author has written a companion book, "The Wave Nature of the Electron," and both are recommended for purchase for the library, at the very reasonable price.