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On Progress

ONE of the necessary duties in an editorial office is the reading of the contemporary journals of other countries in order that we may be conversant with the progress and development outside these Isles, and from time to time make comparison with our own achievements.

Reading through these journals we are frequently struck by the resourcefulness with which well established principles are adapted to new and unexpected applications.

It is not surprising that the electronics computor should offer a number of interesting possibilities, but one of the most intriguing to reach us comes, not unnaturally, from Chicago. According to our information an electronic umpire has been developed there for the American game of bowls, and that attention is now being given to a similar machine for baseball.

In the assessment of the possibilities of such a machine, the report is careful to point out, however, that its reception by the spectator may be hostile since it will not respond to any exhortations to "play the game.'"

By comparison, our own efforts in this direction have been almost negligible, and our outlook somewhat different. We have tended to keep our referees—and indeed what would be the point in going to Highbury on Saturday afternoon without a referee?—and to concentrate our efforts instead on machines to play our games for us. Our readers will recall that we have already made a humble start in this direction with a "noughts and crosses" machine which incidentally contains a built-in referee to ring a bell should its human opponent attempt to cheat.

However, should we feel depressed at our lack of enterprise we have one solid achievement to record this month, and it is not inappropriate that this issue contains an account of the demonstration of the London-Birmingham Radio Relay Link and that it coincides with an article commemorating the birth centenary of Sir Ambrose Fleming.

The Sutton Coldfield Television Transmitter itself will be the largest in the world with its powers of 35 KW (vision) and 12 KW (sound), and it is claimed that nowhere else in the world does there exist a television radio relay link so technically advanced for continuous public service and which offers such possibilities in telecommunication projects.

Professor MacGregor-Morris in his commemorative article on Sir Ambrose Fleming says "On certain occasions it is well to pause and take stock of the achievements made in a rapidly growing subject and to consider to whom we owe the initial stages of its inception."

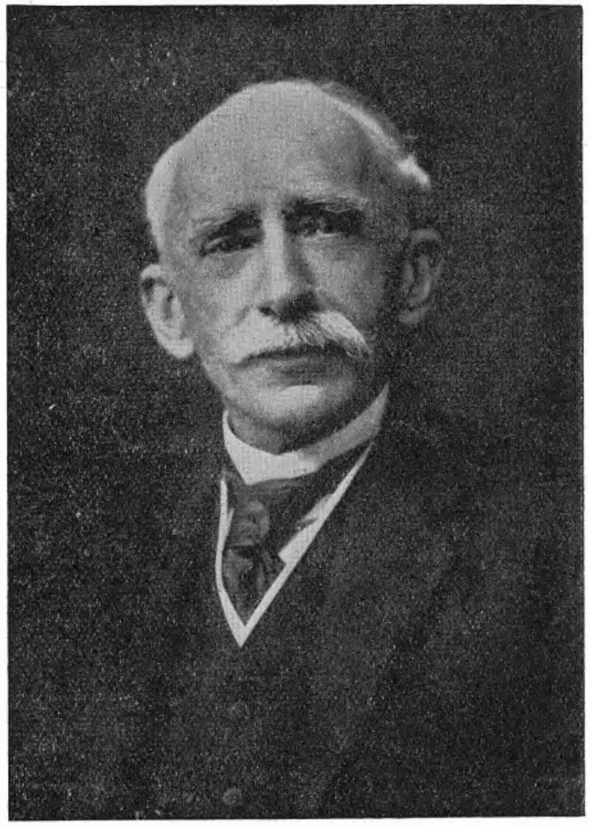
In our opinion, the demonstration of the London-Birmingham link is such an occasion.

Birth Centenary of Ambrose Fleming

. . . November 29, 1949

PART I

By J. T. MacGREGOR-MORRIS
D.Sc. (Eng.) London, M.I.E.E.*



SIR AMBROSE FLEMING

(Courtesy, The Television Society)

ON certain occasions it is well to pause and take stock of the achievements made in a rapidly growing subject and to consider to whom we owe the initial stages of its inception. The present moment seems a suitable occasion to pay tribute to an outstanding figure.

In this journal it is fitting to commemorate the centenary of the birth of Ambrose Fleming, which occurred on November 29 this year, and we propose to do so by giving a brief account of his life and his contributions to Electrical Engineering, together with a more extended description of that part of his work which contributed to the foundation of Electronic Engineering—such as his work in the field of radio valves, cathode-ray tubes and the measurement of the length of electric waves.

If added emphasis be needed for such a course it is contained in a recent utterance of the Vice-Chancellor of Oxford University, made only a few days ago, when he said "I do not know of any subject or study in which, in recent years, the divorce between present practice and past history had been so complete as in the domain of science . . . thus while stress was laid on the up-to-date practical pursuit of science the long period of preparation and development which had led up to it should not be neglected."

Therefore in this article we shall examine the background of scientific knowledge which existed some three quarters of a century ago, and then study how Fleming reacted to it as he grew up, later to become one of our leading electrical engineers.

State of Scientific Knowledge in the 1870's.

It is difficult for us to place ourselves in the position of such pioneers when the phrase "Electrical Engineering" had hardly been coined. To mention only a few of the practical men of the time, there were Swan, Edison, Hughes, Sir Wm. Siemens, Crompton, and, of the scientists, Wheatstone, John Hopkinson, Wm. Thomson (afterwards Lord Kelvin) and Ambrose Fleming.

At that time most public lighting was done by arc lamps, and for street lighting, as in the City of London, some 40 arcs were run in series supplied with commutator rectified A.C. current, each giving a light output of some two-thousand candles. In those days one of the great topical subjects was that of the sub-division of the electric light, i.e., the production of a lamp suitable for domestic use.

Further, whether transformers should have primaries connected in series or in parallel was still a moot point; also why or how an A.C. transformer worked was so little understood that a great Patent Office refused a patent for a transformer, on the grounds that one could not get out of anything more than one put into it!—in this case it was the current in a step-down transformer.

Electrical Engineering started as Electrical Technology, being a rather crude combination of physics and engineering; before this there was only wire telegraphy to absorb the attention of practical men with a bent for electricity. The electric telephone had not been invented.

In much the same way we have seen a similar change occurring in radio engineering from the enthusiastic wireless crank of half a century ago to the well established radio engineer of the present day.

Survey of the Life of Ambrose Fleming

John Ambrose Fleming, born November 29, 1849, was the eldest son of the Rev. James Fleming, D.D., a Congregational Minister in Lancaster. In the late autumn of 1853 the family moved to Kentish Town, London, where the father continued his ministry until his death in 1879. John Ambrose

* Emeritus Professor of Electrical Engineering in the University of London.

showed an early liking for things mechanical, and a growing interest in experimenting. In fact, as he himself said, he was more interested in things than in people.

As he grew up he took a great interest in chemistry. After attending University College Boys' School (London) as a day boy, he entered, in 1867, the college of which the school building formed a part, and in 1870 he was one of the two successful candidates in the First Division of the degree of Bachelor of Science.

A short term of work in the drawing office of a firm of shipbuilders in Dublin was succeeded by some two years spent as a clerk on the Stock Exchange. As this work finished by 4 p.m. Fleming had considerable spare time, which he devoted to improving his knowledge of chemistry, physics and mathematics.

It is interesting that the art of popular scientific exposition was not neglected, for he gives an account of an early experimental lecture which he gave to his parents, and brother and sisters—elaborately prepared in the dining room of their house, concluding with the giving of an electric shock simultaneously to all the assembled audience, with most satisfying results—to the lecturer.

At the age of 21, (1870) he was appointed Science Master at Rossall College where he stayed for two years. Then from 1872-74 he studied at the Royal College of Science; chemistry under Dr. Edward Frankland, and physics under Dr. Guthrie.

By 1874 he was back again at teaching—this time as Science Master at Cheltenham—on the modern side. During the three years in this post Fleming was getting dissatisfied with the limited scope of his knowledge of physics and more especially of mathematics.

To make up this deficiency he decided in 1877 to go to St. John's College, Cambridge, to improve his mathematical knowledge, but specially to work under the famous Clerk Maxwell, the first director of the Cavendish Laboratory, which institution has had a continuous succession of professors of world-wide reputation including Sir J. J. Thomson and Sir Ernest Rutherford.

After the death of Clerk Maxwell in 1879, Fleming undertook some work as demonstrator in the University, during which period he obtained in 1880 the degree of D.Sc. of London.

In 1882 he was appointed to the newly created chair of Mathematics and Physics at Nottingham as its first occupant.

Though he made a success of this new appointment the attractions of London were too strong for his rather practical nature, so he left at the end of the session to join the Edison Electric Light Company. Professor John Hopkinson was their "scientific adviser" while Ambrose Fleming was their "electrician"—probably the term "electrical scientist" would convey nowadays a better idea of his position.

Professor at University College, London, 1885 to 1926

It was not long, however, before he returned to the professorial ranks, this time to the college of his early student days, University College London (Fig. 1), for in 1885 he was apoinpted the first Professor of Electrical Technology at that college. He was to hold this post for a period of over 40 years. This period covers the extraordinary growth of wire telegraphy and telephony, electric lighting, traction, and later the start and growth of wireless valves, amplifiers, oscillators, photo-electric cells, the cathode-ray tube, electron-optics and television; which vast array of subjects is now known as Electronics. During the whole of these 40 years Fleming directed his department with vision and enthusiasm so that University College London was in the forefront of many of these developments.

It was early in this period, in 1887, that he married his first wife, Clara Ripley Pratt, who died in 1917.

(i) Transformer Tests

We shall now follow more closely some of Fleming's achievements during this period of 40 years. From 1885 to 1895 Fleming was one of the leading exponents of the theory of alternating current transformers, and of their practical performance. Incidentally the two volume treatise which he wrote on "The Alternate Transformer" was for many years the premier treatise on the subject. In one of his diaries he states that this book was written in its entirety after 10 o'clock at night.

In 1890 Fleming was engaged on an almost classical investigation on the behaviour of power transformers under various conditions of load. That we may understand the difficulties of making reliable measurements of alternating voltage, current and power, we should recall the fact that the only trustworthy instruments available at that time for such purposes were the Cardew Hot-Wire Voltmeter and the Siemens' Electrodynamometer, apart from the Kelvin Electrostatic Voltmeter and the Kelvin ampere balance. The Wattmeter for alternate current measurements of power was hardly existent, and the importance of reducing the inductance of the shunt circuit of the wattmeter in comparison with its resistance, when the load was highly inductive, was only beginning to be appreciated by practical men. In fact, Fleming and Swinburne actually constructed their own wattmeters, and even then such men laboriously checked their results by the 3-voltmeter method which re-

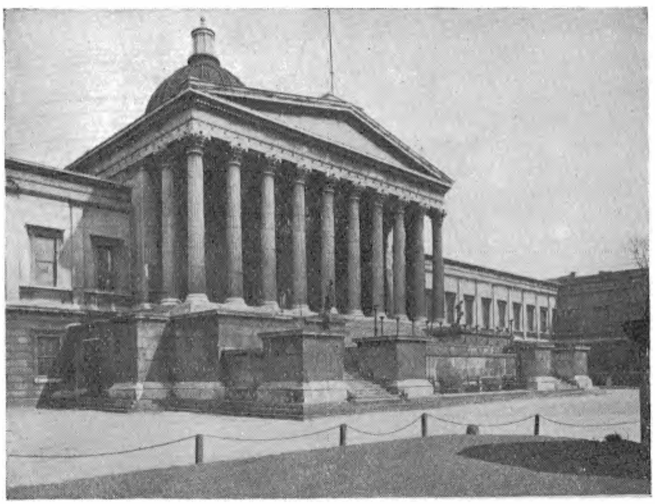


Fig. 1. University College, London. The electrical laboratories where Professor Fleming worked are on the first floor, to the right of this photograph

(Copyright, Country Life)

quires a supply giving about double the working voltage of the transformer, a condition not always easy to obtain.

During the work on these transformers the development of the instruments and the low voltage part of the testing was done at University College, but by far the greater part was carried out at the Engineering Offices of the London Electric Supply Corporation, Adelphi Arches, Charing Cross. At this time Mr. J. C. Shields was Dr. Fleming's assistant, and he spared no pains to ensure that the results were reliable. The experiments extended over a period of five months.

All the results were collected together in a paper entitled "Experimental Researches on Alternate Current Transformers," which Fleming presented to the Institution of Electrical Engineers in November 1892. The paper excited great discussion. The presentation of the paper, and the discussion occupied five consecutive Thursday evenings, and it was not until February 9, 1893, that Fleming was allowed to reply, and he took the whole evening to do this.

Undoubtedly this paper and the discussion which it evoked was a great contribution to the clarification of the operation of power transformers.

Fleming did not let the grass grow under his feet, for as a result he delivered four Cantor lectures to the Society of Arts on "Practical Measurements of Alternating Currents" and these were illustrated fully by experiment. Later on he was asked to direct and arrange to carry out further experimental investigations, this time for the City of London Electric Lighting Company on the ageing of core losses in transformers, and later, on the waveform of the alternators at Bankside on open circuit and when on load.

We have examined this branch of his work, so as to bring out its thoroughness and to bring home the fact that it was his combination of the mastery of the underlying principles involved, and a real gift of exposition, which resulted in practical men coming away from his Cantor and other lectures feeling that they had got hold of something of which they could make use.

(ii) Illuminating Engineering

As our second example, we take Fleming's contributions to the development of electric lamps of the filament type, and their photometry. From 1885 to 1895 the Gas Referees and Examiners were the principal users of photometric methods in London, as they were appointed to ensure that gas supplies were up to the specified standard of illuminating power. Their tests were carried out chiefly by trained chemists, working at various stations throughout London, at irregular times, these times being entirely unknown to the gas companies. The Bunsen "Grease-spot" was the photometer, and originally the standard was the "good old Parliamentary Candle" made of the best spermacetic wax, and burning 120 grains in the hour. As it very rarely burned at the specified rate, and as there was no legally agreed factor for correcting the light output when the rate of burning departed from the 120 grains/hour—it was a most untrustworthy standard. Furthermore, it was affected by draughts, variations of barometric pressure and degree of humidity of the atmosphere; its only real qualification as a standard was that of simplicity. Oil and pentane flame standards, with or without Methven slits were being tried out, and as a result the Vernon Harcourt 10 C.P. Pentane Lamp became established at a later date as the standard, but here again there were uncertain corrections, for barometer and moisture and also for vitiation of the atmosphere. At this time errors of 10 per cent or more were quite likely.

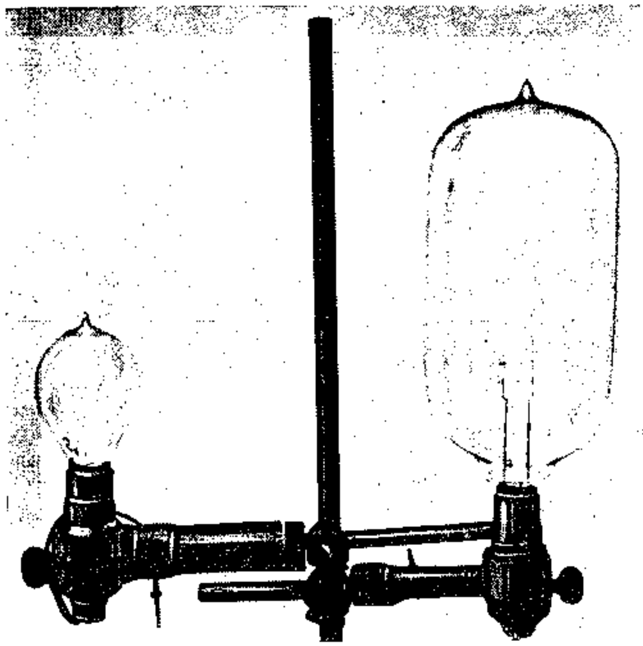


Fig. 2. One of Fleming's "Pendar" large bulb carbon filament standard lamps (*right*) and a contemporary commercial 32 c.p. carbon lamp (*left*)

(Courtesy, The Television Society)

Such then was the unsatisfactory position when Fleming brought his powers to bear on the subject. Owing to his connexion with the Edison and Swan Company as "advising electrician" from 1883 onwards he had ample opportunities of estimating the importance, as well as the difficulties, of accurate photometry.

I cannot do better than take the rest of this section from my friend Arthur Blok's Third Fleming Memorial lecture delivered in 1948, as Arthur Blok himself was also an enthusiast about illuminating engineering.

Speaking of the position at the turn of this century, he says:

"Fleming had long regarded photometric work as a necessary component in electrical engineering training and the light-testing gallery at University College was, according to the standards of the nineties, remarkably well equipped. He seemed to have a prophetic knowledge that electric lighting was soon to become a matter of skilled engineering . . . For years Fleming had been focusing his attention on the possibility of a practical standard of light intensity which would be less variable and more a working tool than the erstwhile oil lamp standards.

"He had turned, therefore, to

incandescent filaments *in vacuo* and he had initiated much work on the changes in luminous emission from carbon filament lamps, whether caused by changes in the filaments themselves or by blackening of the bulbs. At the Pender laboratory at Gower Street we were all in this and would often emerge from the photometric gallery after hours of close work with the Lummer-Brodhun photometer blinking like owls in the noon-day sun. The result of all this work was the setting up of the "Pender" series of standard lamps comprising carbon filaments which had been seasoned *in vacuo* and were then remounted in large new bulbs, so big as to minimise blackening. (Fig. 2.) They may, I think, be regarded as the foundation on which all subsequent practice in incandescent filament standards was based."

(iii) Telephonic and Radio Frequency Research

For a third example of Fleming's method we might take his contributions to the study of the properties of dielectrics at telephonic frequencies. These were partly undertaken in conjunction with the late G. B. Dyke; also his notable work on the Edison effect culminating in the introduction of the "Fleming" valve as the first reliable receiver of radio signals and one with which measurements of signal strength could be made. In addition there is his work on the measurement of the length of electric waves (a "cymometer" is shown in the foreground of Fig. 3) and on cathode-ray tubes.

Enough, however, has been said to show Fleming's method, i.e., that of concentrated study combined with experiment. As the work proceeded he added experimental lectures to scientific bodies, as well as to his students. In each subject which he took up it will be found that a substantial contribution was made to the practical side of the subject, sometimes in the form of a practical contribution to the instrumental side, sometimes by means of an I.E.E. paper, and again at other times in the form of a treatise on the subject.

Electrical Measurements

To present-day engineers it is amusing to recall the primitive arrangements which were in use in the early days for the supply of electric current operating electric arcs in lighthouses. As the generating plant required considerable space, and the fuel used was coal, only lighthouses on the mainland could use such equipment, for example, the North Foreland and the Lizard.

About a century ago, when such sources were introduced, alternating currents were used. The alternator had a set of permanent magnets for its field, and was driven by a steam-engine supplied from a coal-fired boiler. The electric circuits were reduced to as simple a form as possible for the sake of reliability, thus reducing risks of failure of the light to a minimum.

In those days practical electrical measuring instruments were only beginning to be developed, and so no ammeters or voltmeters were included, nor for that matter any fuses, nor any automatic safety devices, as these had hardly been thought of. Thus the attendant had no means of knowing what was the correct speed at which to run his engine to produce the best performance of the electric arc, and I have it on good authority that the attendant ran up his alternator to what he thought was the right speed, and then popped his head out of the engine room to have a peep at the arc. If it was not bright enough he put on a few more revolutions, if too bright he screwed down to stop-valve a bit.

As the months went on the attendant found that he had to run his alternator faster in order to get enough light. This was due to the fact that the permanent magnets were getting weaker with use. When the engine was running uncomfortably fast, a change-over had to be made to a spare set, while the magnets of the first machine were dismantled and re-magnetised.

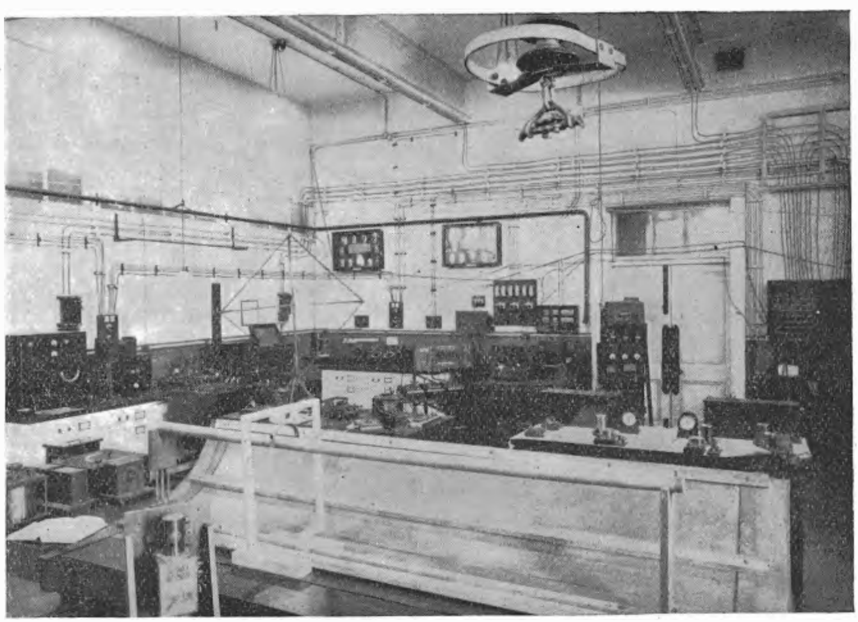
Such then was the position when many of the leading electricians like Siemens, Swinburne, Wm. Thomson, Evershed, and others, tried their hands at inventing measuring instruments.

As for Fleming, he developed an alternating current voltmeter, the direct current potentiometer and an alternating current wattmeter. Of these only the D.C. potentiometer has survived.

In 1882 his attention was turned to the need for quick and reasonably accurate workshop methods of measurement. Perhaps his mind was further stimulated in this direction by his contact with another pioneer in electrical engineering, the late Col. R. E. B. Crompton.

It is clear that Fleming was the originator of the idea of making the apparatus direct reading by using the simple device of connecting in series with the Poggendorff potentiometer, a continuously adjustable resistance (see Fig. 4) which is adjusted through the medium of a standard cell of known E.M.F., so that the value of any unknown voltage can be read off directly in volts. Avowedly this is a very simple addition, but it resulted in

Fig. 3. The first telecommunications laboratory for undergraduate teaching, University College, London



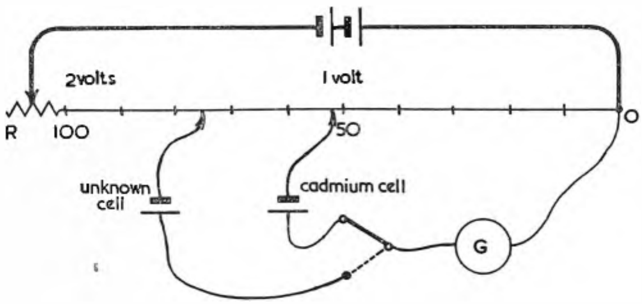


Fig. 4. Fleming's modified Poggendorff potentiometer for direct reading of unknown cell E.M.F.s

the arrangement being adopted almost immediately for practical work. It was in 1883 that Fleming made the first direct reading potentiometer set to read current and voltages in amperes and volts. During the next few years Crompton turned it into a more practical shape, abolishing mercury cups, and altering other items, so that it became more portable.

At first it was possible to attain an accuracy of perhaps ¼ per cent. Nowadays, owing to the better knowledge of materials available, and to the introduction—first of the Clark cell and later of the Weston cadmium cell, the accuracy of such measurements has been increased by at least one hundred-fold, but even in its modern form it still embodies the Fleming principle of direct reading, and the Crompton desire for compactness and portability; indeed, as we all know, it has become an absolute necessity for any laboratory worthy of the name.

Quite naturally such pioneering work in the field of electric measureing instruments and their use in testing dynamos and other apparatus forced upon Fleming the real need for the establishment of some authoritative body which could certify as to the correctness of their indications.

Urged by this conviction we find in 1885, Fleming prepared a paper to read before the Society of Telegraph Engineers and Electricians (later to become our I.E.E.) entitled "On the necessity for a National Standardising Laboratory for Electrical Instruments" which resulted in a proposal for a National Electric Standards Laboratory.

However, though this paper may be considered to be the starting point of the movement, it was not until 1890 that the Board of Trade Electrical Standards Laboratory (Fig 5) was established, at first under the direction of Major Cardew, and later Mr. A. P. Trotter. The work of this laboratory was finally transferred to the National Physical Laboratory, Teddington, which was founded in 1901.

Measurements at Radio Frequencies

Many years later when the new subject of electric wave telegraphy was being developed, Fleming again turned his attention to devising measuring instruments, this time suitable for the new technique.

Thus we find him at work on apparatus for the measurement of small capacitances and inductances, and such apparatus was developed in conjunction with his right-hand man, Mr. (afterwards Professor) W. C. Clinton, while later on, with the help of his assistant, Mr. G. B. Dyke, he developed other apparatus and carried out tests in this new field.

Then his electric wave measurer—called by him a cymometer—was probably the first practical device for measuring the length of long electric waves. This was in 1905.

Popular Scientific Lectures

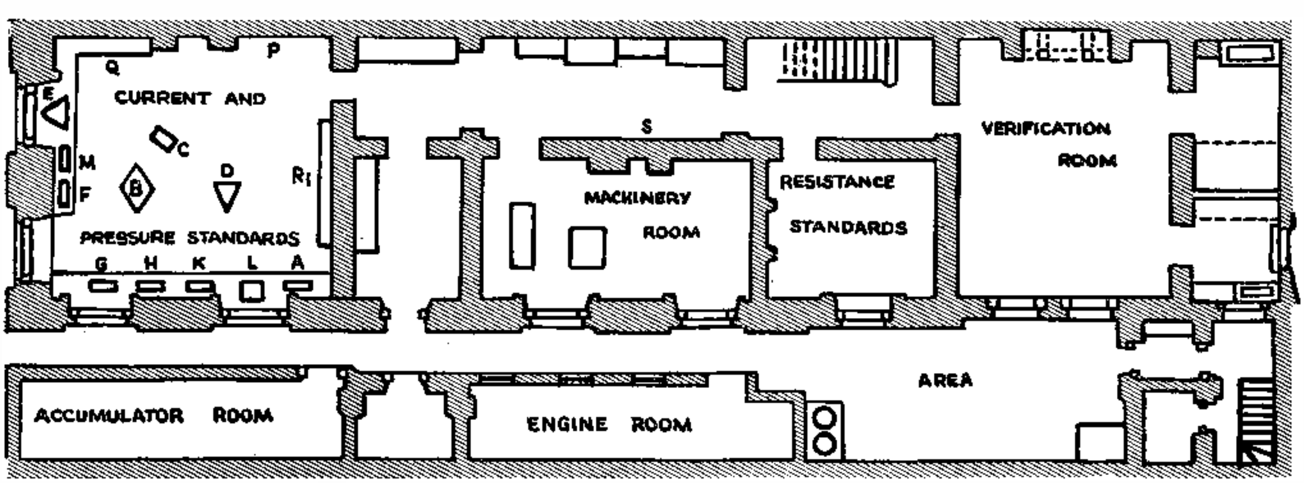
No account of Fleming's activities could have any semblance of completeness were it not to make reference to his popular scientific lectures. Fleming's ideal in these lectures was that of Michael Faraday, and I venture to think that Ambrose Fleming was a very good second to that "prince of scientific lecturers."

Quite apart from his highly successful Christmas lectures for juvenile audiences at the Royal Institution, Fleming was in great demand by many of the larger provincial lecture societies from Greenock in the north to Portsmouth in the south. In one session he delivered 24 such lectures, practically all of which were experimentally illustrated. Many of the experiments were devised to be shown as shadows of miniature apparatus working in the lantern slide carrier, thus being easily visible to the entire audience and at the same time contributing greatly towards portability.

Retirement at Sidmouth

On Fleming's retirement in 1926 he settled at Sidmouth, where he had built a house.

Fig. 5. Floor plan of the Board of Trade Electrical Standards Laboratory where measurements commenced in 1894



For some years he often went up to London visiting his old college, and, as Dr. W. H. Eccles writes in "Nature," he (Fleming) "was quick in his movements. This celerity was characteristic; even when he was in the middle seventies, one could see his linear figure threading quickly a populous corridor in the College, intent on a goal, looking neither right nor left, overtaking everybody. Indeed, in intellectual as well as material things Fleming's main principle of action was full-speed ahead."

In 1933 he married as his second wife Miss Olive May Franks, "a singer of wonderful charm"—who survives him.

For over fifteen years he was president of the Television Society of London. He was an ardent supporter of the late J. L. Baird—that remarkable inventor of television whose success was due to his foresight and continuous pertinacity in spite of great opposing forces. Fig. 6 shows the two friends together on the occasion of a television demonstration.

Honours came to Fleming late in life, but when they did come they were showered upon him. In 1929 he received a knighthood, and, among other honours, the Hughes Medal of the Royal Society. He was made Emeritus Professor in the University of London in 1926, Honorary Fellow of St. John's College, Cambridge, 1927, Faraday Medallist of the I.E.E., 1928, and was awarded the Radio Medal, U.S.A., 1933, and the Franklin Medal, U.S.A., 1935.

Conclusion

Fleming was always intensely interested in any phenomenon connected with sparks, arcs and the discharge of electricity in semi-vacuous spaces such as the old-fashioned Geissler tubes and the modern neon tubes, the production of X-rays and the Edison effect, i.e., the conduction of negative charges across vacuous spaces.

He examined experimentally with enthusiasm the Edison effect on his return from America in 1885, reading a paper to the Physical Society of London on his experiments and giving a Friday evening discourse at the Royal Institution, London.

Later, in 1896, he made a further study of these effects, the results being published in a Physical Society paper in that year. About the same time he studied the focusing of a beam of cathode rays by means of a short or squat solenoid and also the properties of X-rays, and later the subject of photo-electricity.

It will be noticed that all these have to do with the behaviour of electricity in spaces between solid (or liquid) conductors, in fact, studies of the behaviour of free electrons in gases or rarified spaces.

It is now clear that such studies were a first-class preparation for the understanding of the subject of electronic engineering which was yet to be born, thus preparing Fleming to make the great advance of the application of the Edison effect to radio-telegraphy reception. It shows the importance of taking a lively interest in new phenomena which may not be obviously of direct value to one's immediate work, if one has reasonable hope of making major contributions to one's profession.

The younger generation of scientists and engineers have not perhaps such opportunities of making radical new discoveries in our profession as had Fleming and his contemporaries, but there is no doubt whatever that any young man or woman who essays to make electronic engineering his or her life's work, should, like Fleming, see to it that their knowledge rests on broad foundations, including such subjects as physics and mathematics, and for that matter chemistry. By so doing, when any new discovery comes along they will be able to get to grips with the fundamentals of the phenomenon, and thus be in the forefront with those who are able to use such knowledge with certainty for practical applications.

In Fleming's life we see this aspect illustrated time and time again, e.g., in the case of the practical application of transformers, the development of electric lamps of the filament type and in the invention of the radio valve—to take only three cases.

In addition to such individual pioneering, the importance of trying to understand the other fellow and his point of view is becoming more and more essential, as much of our scientific work, especially on the engineering side, has to be done by teams. This side of present-day research and development cannot be overstressed. The days for such men as Faraday, Hughes and Heaviside may be largely over; they ploughed their lone furrows; instead, we find the loosely-knit teamwork led by such men as Sir J. J. Thomson and Sir Ernest Rutherford with "families" of scientists or the equally important teamwork of such groups as, for example, the T.R.E., which have come to the front in recent years.

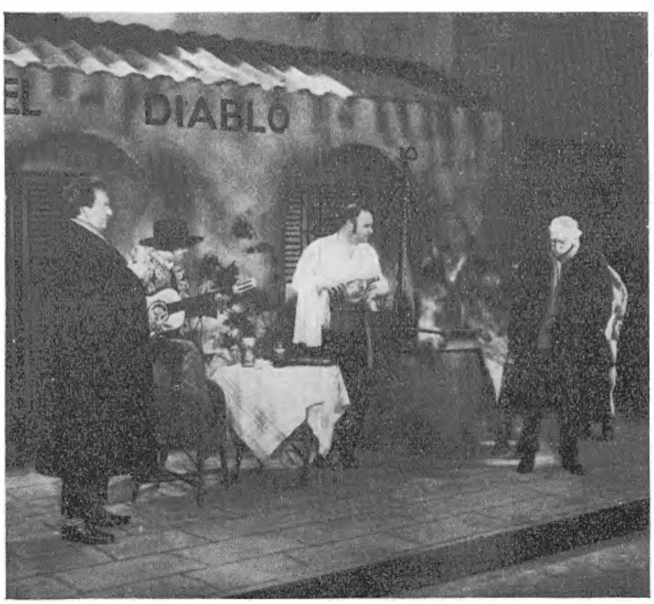


Fig. 6. Sir Ambrose Fleming and J. L. Baird in the Baird Television Company's studio at the Crystal Palace, 1936.

(Courtesy T. M. C. Lance)

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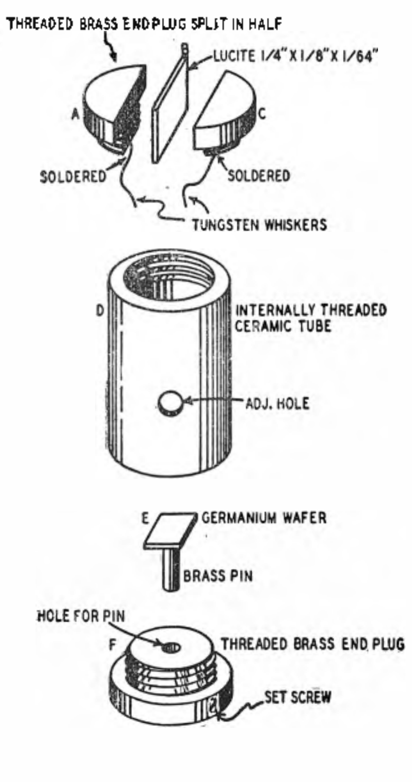
An Experimental Crystal Amplifier

WRITING in *Radio-Electronics* for May 1949, Rufus Turner describes an experimental Transistor which was made for him by R. Jacobson, using a 1N34 germanium diode. As these rectifiers are fairly readily available from surplus disposal stores, this account of the making of a Transistor is reproduced for the benefit of those wishing to experiment with the new amplifier.

An account of the operation of the Transistor was given in ELECTRONIC ENGINEERING for September 1948. The following notes deal with the construction and testing of the unit. Two 1N34's will be required to provide the two catswhiskers, leaving a spare crystal.

The 1N34 consists of two threaded brass end plugs which are screwed into opposite ends of a small ceramic tube. The tungsten whisker is soldered to one of these plugs and rests upon the surface of the germanium wafer. The wafer is soldered to the end of a brass pin passed through a central hole in the other end plug

Fig. 1. An exploded view of the transistor when ready for assembly



and held by a setscrew. These parts are all shown, ready to go together, in Fig. 1. After adjustment at the factory, the ceramic tube is filled with wax. This wax has been injected through a hole in the side of the ceramic tube; this hole served previously for an access point through which the whisker could be moved about to various spots on the germanium surface during electrical adjustment.

After obtaining two 1N34's, the first step in the construction of the triode is carefully to pick out the sealing material which plugs the hole in the ceramic tube of each unit. This may be done with a needle, being cautious not to dig any deeper into the unit than the thickness of the ceramic wall. The next step is slowly to melt out the wax by heating the entire unit. Hold it high over a low flame. Make no attempt to rush this operation. The wax will run out through the side hole. After the wax has been expelled, the tinned ferrules which hold the pigtails may be peeled off the end of each unit with the aid of diagonal cutters. This will expose the two brass end plugs which then may be unscrewed.

After removing the end plugs, unsolder the whiskers from their plugs and bathe them in carbon tetrachloride. The next step requires painstaking care: saw one of the whisker plugs vertically in half, using the thinnest obtainable jeweller's saw blade, to obtain the two separated halves as shown as parts A and C in Fig. 1. Solder one whisker to each half. The tungsten wire is a little tricky to solder and may require acid soldering flux. If the latter is used, wash the finished job thoroughly in strong soapy water, give several rinsings in clear water, then dry the parts and bathe them in carbon tetrachloride. Next, using Duco cement, fasten the two halves of the split end together with an insulating separator (part B in Fig. 1) made from Lucite or Plexiglas 1/64 in. thick. Be careful to keep the threads of the split plug aligned. Then, with a needle, toothpick, or slender tweezers, bend the tips of the whiskers together until they have the smallest separation without actually touching each

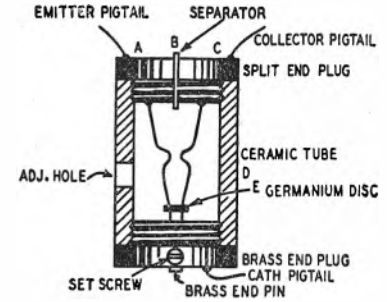


Fig. 2. The assembled crystal amplifier

other. It will help to use both a magnifying glass and continuity meter in this operation.

Screw the two-whiskered plug back into one end of the ceramic tube, and the germanium-holding plug F into the other end. Using a magnifying glass look through the tube hole to see whether the whiskers are both in contact with the germanium surface and also whether threading in the germanium plug has twisted them. If the whiskers are twisted or are touching each other, separate them with a needle or tooth-pick inserted through the hole. If they are spread too far apart, push them closer together with the needle. If the whisker

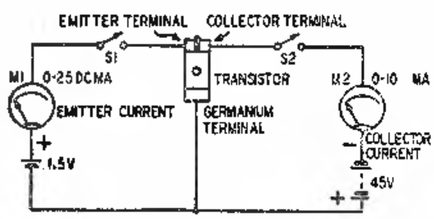


Fig. 3. Test circuit to measure transconductance

tips are not in contact with the germanium surface, loosen the setscrew in the germanium end plug and cautiously push the end of the germanium pin inward by means of a pin inserted into the centre hole of the plug, until contact is made. Then retighten the setscrew.

The final step is to solder a wire pigtail lead to each half of the split whisker plug (A and C in Fig. 2) and also to the germanium plug F. The soldering operation must be completed quickly in order not to melt the solder holding the whiskers or damage the germanium wafer.

Throughout the construction, take care not to handle the germanium wafer or the whiskers with the fingers any more than is absolutely necessary. If there has been excessive handling, both the whiskers and the germanium wafer should be bathed in carbon tetrachloride or lacquer thinner.

Fig. 2 shows how the completed transistor assembly appears in cross section. Letter symbols are the same as those in Fig. 1. The distance between the catswhiskers is exaggerated in the sketch.

Adjustment

After the unit has been assembled, set up the test circuit shown in Fig. 3, and test the crystal triode according to the following procedure. Either half of the split end plug may be chosen as emitter or collector.

1. With switch $S2$ open, close switch $S1$. The emitter current, read with milliammeter $M1$, should not exceed 20 mA and undoubtedly will be in that neighbourhood at the outset.*

2. Open $S1$ and close $S2$. The collector current, read with milliammeter $M2$ should not exceed 0.5 mA.

3. If emitter or collector current is in excess of the values given, reverse the emitter and collector terminals and repeat steps 1 and 2. If the currents still are excessive, unscrew the germanium end plug, loosen the setscrew, and rotate the germanium pin to expose new surface points to the whiskers. Re-insert the end plug, respace the whiskers.

4. Close switch $S2$ and record the reading of milliammeter $M2$ as $I1$.

5. Leaving $S2$ closed, close $S1$, noting the new reading of milliammeter $M2$. Record this second $M2$ deflexion as $I2$.

6. The transconductance is

$$\frac{1{,}000\,(I2 - I1)}{1.5} \text{ micromhos.}$$

The builder should aim for the highest transconductance he can obtain with a given germanium wafer. Magazine articles have reported transconductances as high as 15,000 micromhos. The author has found that transconductances of 1,000 to 3,000 (comparable to such tubes as the 6J5, 6SQ7, 6T7, etc.) may be obtained readily with little or no adjustment on a transistor of the type described in this article. Rotating the germanium wafer to expose better spots to the two whiskers has yielded transconductances a little higher than 5,000.

After all adjustments are completed, the side hole in the ceramic tube should be closed with a small piece of Scotch tape. We do not recommend filling the interior of the unit with any of the waxes ordinarily available to the home experimenter.

* The Editor of *Radio Electronics* comments that the 20 mA emitter current is very much greater than the figures commonly published. These range from a fraction of a milliampere to 1 or 2 mA. Transistors made by different experimenters vary widely for reasons still unknown. The performance of transistors made by readers therefore may be entirely different from that of the one described here.

DISCRIMINATOR ADJUSTMENT

A DIFFICULTY encountered in the lining-up of discriminators in F.M. receivers or in A.F.C. circuits is that the test instrument, connected into the circuit for the purpose of alignment, introduces an additional capacitance. The adjustments are carried out with this capacitance across the circuit and, when the test instrument is disconnected, the circuits will no longer be in correct adjustment.

A method of avoiding this error is to provide a valve voltmeter in the form of a diode with a load resistor permanently connected in the circuit. For instance, the diode may be connected to the anode of a valve driving a Foster-Seeley form of discriminator and the low potential end of the resistor may be earthed through a link. When adjustments are to be made, the earthing link is replaced by a suitable micro-ammeter. Alignment consists in adjusting the primary circuit for maximum deflexion and the secondary circuit for minimum deflexion.

If, for economy, it is desired to incorporate the voltmeter diode in the same envelope as that used for tuning indication, it will usually be found that the coupling between them is undesirably large. This may be nullified, without loss of economy, by using a double-diode-triode valve with the two diodes strapped together as a part of the tuning indicator circuit and the grid-cathode portion as the voltmeter diode. The necessary shielding between the two circuits is conveniently achieved by earthing the anode.

The Figure shows a circuit which uses these principles.

—*Communication from*
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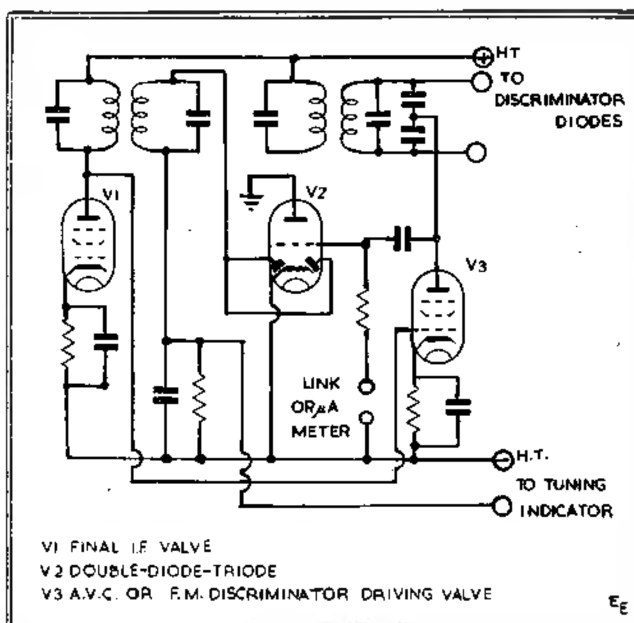

The schematic shows a double-diode-triode valve used in the application described. The two diode anodes are strapped together for tuning indication, and the grid becomes the anode of the voltmeter diode

IONISATION IN GASES—

The Ionisation Chamber and the Geiger Counter

By T. H. D. ATTEWELL, B.Sc., M.I.R.E.

IT has long been known that air, an insulator for all practical purposes, can become conducting in the presence of X-rays and of radioactive substances, and that this is due to the formation of ions and free electrons in the gas. To obtain a picture of the process of ionisation it is helpful to examine the energy relationships of an electron with the atom of which it forms a part.

For simplicity we shall consider first the hydrogen atom, which has a nucleus consisting of one proton, with which is associated one orbital electron. Now it was first suggested by Bohr that the extra-nuclear electrons in an atom can move only in certain definite "permitted" orbits, and that radiation occurs discontinuously in discrete "wave-packets," called quanta, when an electron makes what is, effectively, an instantaneous transition from one permitted orbit to another nearer the nucleus. This is shown diagrammatically in Fig. 1. He further postulated that the energy of the quantum is proportional to the frequency (ν) of the emitted radiation, or :—

$$E' = h\nu \quad \text{.........................} \quad (1)$$

where h is Planck's constant, having the dimensions of action and being equal to 6.624×10^{-27} erg. sec.

With each permitted orbit there is associated a particular total energy E (kinetic plus potential) for an electron placed in it. This total energy is readily calculated for the simple Bohr picture of the hydrogen atom, in which one assumes circular orbits, and also that it is only the angular momentum of the electron which is quantised, that is, restricted to "permitted" values only. It is found that these values are given by $nh/2\pi$ where n is a positive integer, called the principal quantum number, having the possible values 1, 2, 3, . . . etc.

The derivation is given in the Appendix, and, by substituting for

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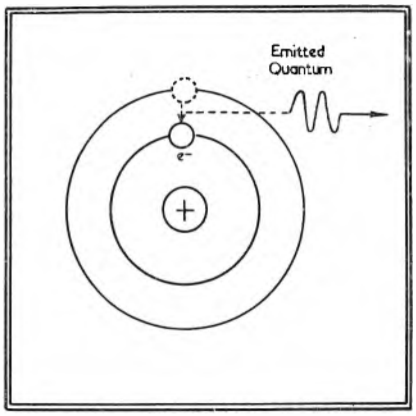


Fig. 1. Electron jump accompanied by the emission of a quantum of radiation

the various quantities in the relation found there we can calculate the value of E for the innermost orbit by putting $n = 1$. Similarly, by putting $n = 2, 3, \ldots$ etc., we derive the value of E for orbits successively further out. Writing these as $E_1, E_2, E_3, \ldots$ etc., respectively, they may be illustrated by the energy-level diagram of Fig. 2. The lowest level E_1 is known as the Ground State and is represented by a horizontal line. Above this are drawn further lines to represent the other permitted levels E_2, E_3, . . . the spacing between these lines corresponding to the differences in energy which they represent. Since $E \propto 1/n^2$, the lines become closer as their level rises until they merge at the terminating level E_n where $E = 0$, (at all other levels E is negative in sign). An electron reaching this level can be said to have escaped from the atom in doing so, and leaves behind a positively charged ion. The energy step marked ϵ_1 is therefore the energy needed to ionise a hydrogen atom in the ground state. Since this involves removing unit electronic charge, we may refer to this step as the ionisation potential, and express it in volts.

The steps $P_1, P_2, \ldots$ are the first and second . . . etc., excitation potentials. An electron might be raised from the ground state to E_3 (say), by the absorption of energy. The atom is then said to be "excited." If the electron now returns direct to the ground state a photon will be emitted according to the relation

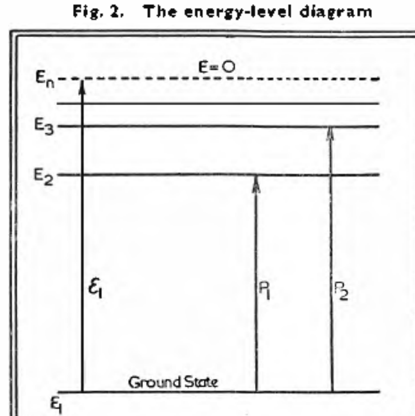
$$E_3 - E_1 = h\nu$$

It must be noted that the above discussion is a simplification of the problem. We have restricted ourselves to circular orbits, and have introduced only one quantum number (n). In fact four quantum numbers are needed to describe the system completely, and we are obliged to relinquish our fixed orbits in favour of the more nebulous concept of a probability-functional charge distribution in space. In more complex atoms the energy levels fall into a number of groups, and not all the possible transitions between levels are permitted.

However, the general picture of ionisation so far given, using hydrogen as an illustration, is sufficient for our purpose, and ionisation in complex atoms can be regarded as the removal of one or more of the outer (valency) electrons. The energy required is not readily calculable as for hydrogen, but may be found experimentally. Some excitation and ionisation potentials are collected for reference in Table 1.

For a more complete treatment of

Fig. 2. The energy-level diagram



the subject a specialised account may be consulted.[1]

Negative Ions

In addition to ionisation by the loss of an electron, there is a second ionising process. Some atoms in particular show a tendency to acquire electrons in excess of their normal complement, so forming negative ions. Fluorine, chlorine and oxygen are typical examples. The tendency to form negative ions is predictable from the electron affinity of the atom, defined as the energy set free when enough electrons are added to a gram-atom of the element to convert the whole to ions of normal valency. For fluorine this amounts to 98.5 K.cals. mole^{-1}, while for oxygen it is negative, being -168 K.cals. mole^{-1}. Thus energy is liberated when fluorine "adds on" electrons, and absorbed when oxygen does so, consequently the latter forms negative ions less readily than the former. Negative ions will be referred to in connexion with Geiger counters, but ignored in Ionisation chambers, where their presence does not materially affect the present discussion.

Mobility and Recombination of Ions

If ions are produced at a steady rate, by, let us say, X-rays, in a volume of gas across which a constant potential is maintained between a pair of electrodes, then negative ions and electrons will drift toward the anode, while positive ions move toward the cathode. Under unit field (1 volt/cm.) the velocity for ions is of the order of 1 cm./sec. at normal pressures, and is much higher for electrons, the value for the latter depending on the nature of the gas. The velocity in cms./sec. under unit field at 0° C. and 760 mms. pressure is termed the mobility.[2]

In a system such as that indicated above, not all the ions are actually collected by the field, and in the absence of the field ions do not accumulate indefinitely, even though they are being formed at a constant rate. The reason is simply that ions of opposite sign, or ions and electrons, are frequently in collisions resulting in charge neutralisation with formation of neutral atoms, and equilibrium is reached between the three processes—formation, collection, and recombination. It may be shown very readily that the rate of recombination is proportional to N^2, where N is the number of ion-pairs present, and that recombination alone, in the absence of formation and collection, occurs according to the law:—

$$dN/dt = -\alpha N^2$$

where dN/dt is the rate of disappearance of either kind of ion and α is a constant.

The Townsend Avalanche

If the gas pressure in the system is now reduced, the mean free paths of the particles are increased proportionally. By reducing pressure and increasing the field it is possible to arrive at a condition where an electron (say) is sufficiently accelerated to enable it to eject another electron from the next atom it strikes. The ejected electron may now ionise a further atom. The whole process is cumulative, and results in an avalanche of ions, which may have been started by one electron only. The phenomenon is named after Sir J. Townsend, a pioneer in these studies, and is also referred to as "gas amplification."

Ionising Agents

We may now very briefly summarise the more important ways in which the energy needed for ionisation is provided. These are:—

(a) Collisions with particles whose kinetic energy is used up in ionising the neutral atom and in imparting kinetic energy to the resultant ions. The particles with which we are concerned are ions and electrons already present, electrons from radioactive disintegration (β-particles) and helium nuclei (α-particles).[3] (b) Ionisation by X-and γ-radiation.[4] Of the various possibilities here, two will be sufficient for our immediate consideration:—

(i) The photoelectric effect. An incident photon is completely absorbed by a neutral atom and an electron is rejected. The photon energy appears as ionising energy plus the kinetic energy of the ions formed. Photoemission is proportional to (approximately) the fourth power of Z, the atomic number of the material irradiated.

(ii) The Compton effect. Here the photon is elastically scattered from an electron in an atom, the electron recoiling out of the atom. The emergent photon thus has an energy lower than it had on incidence, but may still be able to ionise further atoms. The effect is relatively independent of Z, and occurs at higher energies than the photoelectric effect. For γ-rays of energy around 5 KeV. and below, nearly all electrons ejected are photoelectrons. At about 100 KeV. the proportion is 80 per cent Compton and 20 per cent photoelectrons, while above 800 KeV. only the Compton effect is of major importance.

Classification of Counters

We have seen how neutral gas atoms may give rise to ions when they absorb radiation of sufficiently high energy (low wavelength), or are in collisions with various particles. The collection of ions so formed provides a method whereby such radiation and/or particles may be detected, and we may now examine the various types of detector, more usually termed "counters," using this principle.

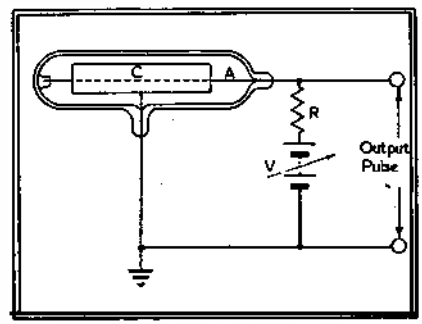


Fig. 3. A basic counter system

Consider the simple arrangement of Fig. 3. Some suitable thin-walled container is provided with a wire anode (A), and a concentric cylindrical cathode (C), and is filled with a simple gas at low pressure, let us say Argon at 10 cm. Hg. The cathode is earthed, and the anode is connected to a variable potential (V) through a resistor (R). Imagine that one single α-particle, entering the space between anode and cathode, gives rise to 10^4 ion pairs, but that a certain β-particle gives only 100 ion pairs on entry. When the voltage V is being applied, either of these events will result in a burst of ions being collected, and hence a voltage pulse appearing across R. We now plot the amplitude of this pulse against V for each of the two events as in Fig. 4, which is not to any particular scale.[5]

Between the origin and A, the pulse heights increase with V as more and more ions are collected before they can recombine. Between A and B, the heights are independent of V and are proportional to the initial number of ions formed. In this region the counter is said to function as an ionisation chamber, and it is apparent that the counter is saturated, that is, for all practical purposes, the whole of the ions initially formed are collected. Until B is reached there is no gas amplification. Above B, however, the field is sufficient to produce gas amplification, and larger pulses are recorded. Between B and C the pulse amplitudes remain proportional to the initial number of ions, and a counter operating in this region is known as a Proportional Counter. The gas amplification factor rises steadily over the region BC, being of the order of 10^4 at C, and continues to rise in the region CD, where, however, the pulse amplitude is no longer proportional to the initial ionisation, rising more rapidly for smaller numbers of ions than for higher. At D, both initial events give output pulses of the same height, and this is the criterion for the commencement of

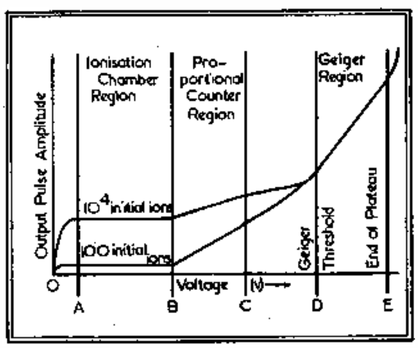


Fig. 4. Pulse height and applied voltage relations in the counter of Fig. 3, taken from S. A. Korff: "Electron and Nuclear Counters," (D. Van Nostrand Company Inc, 1946)

the Geiger region, which extends from D to E. Here the pulse height continues to rise with applied voltage as the gas amplification factor increases, but above E the counter goes into a continuous discharge. Although called continuous, this discharge actually consists of a large number of separate and overlapping breakdowns, in which the gas amplification factor may rise as high as 10^8.

In this manner three types of counter are distinguishable: the Ionisation Chamber, the Proportional Counter, and the Geiger Counter. Each has its own sphere of especial usefulness, but here we shall confine ourselves to the first and last types, which are perhaps in more general use than the Proportional Counter.

The Ionisation Chamber

Ionisation chambers are used mainly for the measurement of X- and γ-radiation and for the qualitative detection of β-particles, and form the basis of numerous health monitors.[6, 7]

The usual arrangement of this class of instrument is shown in Fig. 5. The chamber (*C*) consists of two electrodes held at about 20-100 volts apart by the battery (*B*), and contains the gas, which is usually air at ordinary temperature and pressure. Ions formed in *C* give rise, when collected, to an ionisation current (*i*), which, flowing through a high resistor (*R*), provides the input for the electrometer circuit. (*E*). Indication is usually by a meter directly calibrated in dosage, expressed in röntgens per hour. The electrometer circuits may follow conventional practice and will not be discussed further.

The design of the chamber may be pursued along the following lines. First, the necessary volume of gas must be fixed, since the total ionisation produced by steady irradiation is proportional to this quantity. From the circuitry to be used we find the maximum input voltage required for a full-scale reading of whatever intensity it is desired to measure. Suppose this turns out to be one volt for one röntgen per hour. We next select a value for the input resistor, such that the input time constant is not too high, remembering that the total input capacitance may well lie in the region 10-50 *p*F. Suppose we choose 10^{10} ohms, so that the time constant will not exceed 0.5 sec. Then the ionisation current required will be 10^{-10} amp.

Now one röntgen produces 1 *e.s.u.* of charge in 1 c.c. of air at 0° C. and 760 mm. pressure by definition, so that for 1 röntgen per hour in 1 c.c. of air the ionisation current will be $1/(3600 \times 3 \times 10^9) = 9.26 \times 10^{-14}$ amp. In general, if V is the required volume in c.c., Rg the radiation received in röntgens per hour, and i the ionisation current, then

$$i = 9.26\,V.Rg \times 10^{-14} \text{ amp} \quad \ldots (2)$$

In the above case, therefore, the required volume will be 1080 c.c. In calculating the volume it is advisable to allow for the worst circuit conditions (input resistor on lower tolerance limit, etc.) and then provide a calibration control which reduces the sensitivity of the circuit under better conditions.

We have now to fix the form of a chamber to give the calculated volume, and to satisfy two other conditions, namely, to have the lowest practicable electrical capacitance, and to have an even field distribution. The first of these conditions keeps down the input time-constant, while the latter is necessary if high polarising voltages are to be avoided. If "pockets" of low field are present, recombination is encouraged, and is always proportional to N^2 as we have seen, so that as the incident radiation increases in intensity, more volts must be

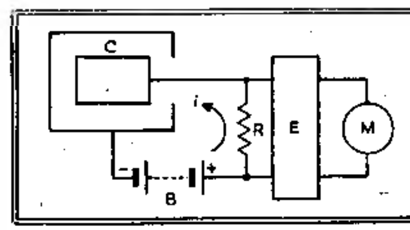


Fig. 5. Block schematic of an ionisation chamber instrument

applied to collect the same proportion of the ions as before. The effect is present in all practical chambers, but becomes serious, introducing non-linearity of scale, where the chamber shape is unfavourable. An example is shown in Fig. 6, where saturation curves for two chambers are reproduced. The three full curves are for a typical cylindrical chamber of some 450 c.c. volume, the indicated intensity (% of *F.S.D.*) being plotted against the chamber voltage for each of the three incident intensities shown. The dotted curve is for the same system, the outer cylindrical wall being replaced by one of square section so as to enclose the same free volume. It is always wise to determine such curves, using an X-ray source for convenience, when a new design of chamber is constructed, so that one can tell at a glance whether the proposed polarising voltage is adequate for the application in mind.

The most usual arrangement to avoid field discontinuities, as far as possible, uses two concentric cylinders as the electrodes. Now, for a point distant r from the axis of two such cylinders of radii r_a, r_b, the field

X in terms of the applied voltage V is given by:—

$$X = \frac{V}{r \log_e (r_c / r_a)} \quad \text{..........} \quad (3)$$

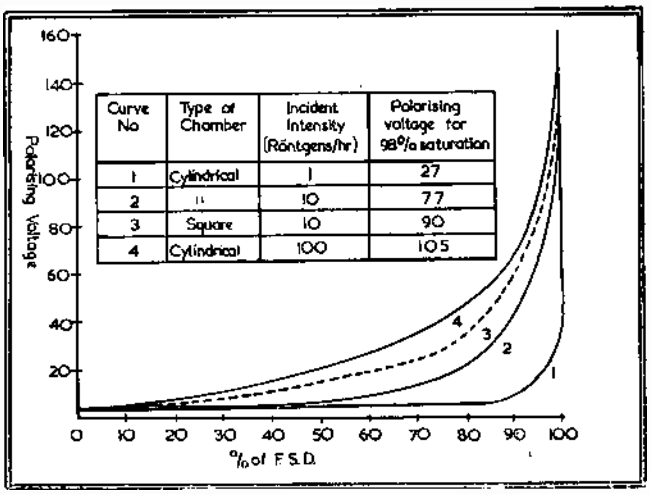
Hence to enclose a given volume between the cylinders, making X as high and as linear as possible, r_c and r_a should be made large, so that $r_a \rightarrow r_c$. Against this must be set the considerations of total bulk and chamber capacity. As a guide to what may be acceptable in practice the chamber used in the experiment of Fig. 6 had the dimensions:—

Collector (anode) 3.8 cm. dia × 6.7 cm. long.

Outer wall (cathode) 8.6 cm. dia. × 9.2 cm. long.

Capacitance approx. 15 pF, assembled, with guard ring.

Next the material for the collector and outer wall must be chosen. When this material is irradiated, electrons are produced by the photoelectric effect and by the



Curve No	Type of Chamber	Incident Intensity (Röntgens/hr)	Polarising voltage for 98% saturation
1	Cylindrical	1	27
2	"	10	77
3	Square	10	90
4	Cylindrical	100	105

Fig. 6 (*left*). Measured saturation curves for an ionisation chamber

Compton effect as outlined above. For γ-ray energies below about 5KeV., nearly all the electrons arise from the photoelectric effect, while above about 800 KeV., nearly all arise from the Compton effect. Since, as stated before, the *P.E.* effect is proportional to Z^4, and the *C.E.* is independent of Z, it follows that the number of electrons removed from the wall and entering the gas will be greater, pro rata, at lower radiation energies than at higher. Now the röntgen is defined in terms of ionisation in air ($Z \approx 7.7$), hence, if the device is to read röntgens directly for all intensities, the solid material of the chamber must also have $Z \approx 7.7$. Many hydrocarbon materials satisfy this requirement to a good approximation, and presspahn, S.R.B.P., etc., are satisfactory. Since a conducting surface is necessary, they must be coated with colloidal graphite. Alternatively, one may use a metal wall (e.g., brass) and line the inside of the outer cylinder and the outside of the inner one with presspahn. This suppresses photoelectrons formed in the brass, and acts effectively as an air wall. Again the inner surfaces must be coated with colloidal graphite, preferably the naphtha- or alcohol-based types, which do not appear to give rise to distortion on drying out. The thickness of all walls must be sufficient to ensure equilibrium between the incident radiation and the ejected electrons, i.e., an electron ejected just at the outer surface must be stopped within the wall thickness. About 1 mm. is usually chosen. If very low energies are to be measured the wall may have to be reduced to permit γ penetration, but the measurement of extreme ranges is outside the scope of this article.

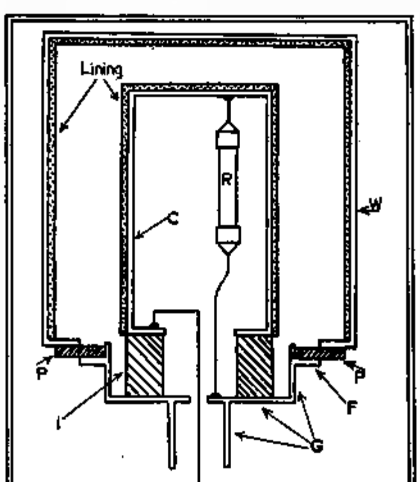


Fig. 7 (*below*). Section showing a typical chamber construction

Detection of β-particles

β-particles cannot be measured quantitatively by the Ionisation Chamber unless the type and geometry of the source are known, but they may be detected qualitatively by allowing them to enter the chamber by a thin window. This may be of wire gauze dipped in a solution of distrene and allowed to dry, thus giving a film of distrene a few mils. thick, and coated thinly on the inner surface with colloidal graphite. The window is made to form part of the outer wall, and should be arranged so that the solid angle for the entry of β-particles from an external point source into the free volume of the chamber is as large as possible. When not in use the window may be covered externally by a metal flap so that γ measurements may be made in the presence of β background if desired. The gauze used may be of mesh between 40 and 80 per square inch, and the wire of which it is made should be as thin as possible, to avoid undue absorption of the β-particles by the metal.

The Guard-ring and Insulator

In Fig. 7 is shown a diagrammatic representation of a complete chamber. The collector electrode (*C*) is supported on the main insulator (*I*), which in turn is fixed to the guard-ring (*G*). This carries a flange (*F*) on which the outer wall (*W*) is supported via an insulator of paxolin (*P*). Regarding the main insulator, a resistance three orders higher than the input resistor used, or in any case not less than 10^{14} ohms, should be aimed at. Volume resistivity is seldom troublesome, but the surface must be lyophobic and perfectly smooth and free from machining marks. Moulded polystyrene or polyethylene are frequently used, but glass should be avoided unless silicone treated; even then it is not completely trustworthy. The insulator must not be handled; it may be cleaned in pure methyl- or ethyl alcohol (A.R.), after which it must be dried thoroughly before use, since the alcohols are slightly conducting.

The guard-ring avoids the appearance of the supply voltage across the main insulator, prevents the col-

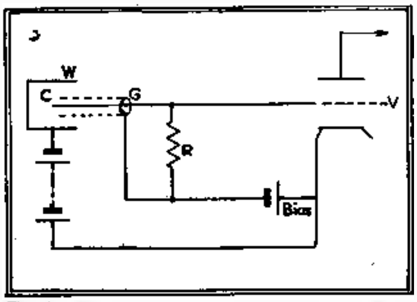


Fig. 8. Connexions to the chamber of Fig. 7

lector from "seeing" any random potentials outside the chamber, and also prevents the deposition of ions on the insulator, which should not be able to "see" any part of the outer wall. The chief practical difficulty is to make the guard-ring effective without too much increase in chamber capacitance, but the design is, fortunately, not over-critical and there is seldom much trouble involved in meeting the requirements. Fig. 8 shows the connexions to the chamber and guard-ring as used with an electrometer (V).

Since quite small changes in the capacitance of the system produce appreciable input voltage changes in the amplifier, most ionisation chambers tend to be microphonic. Their construction must therefore be made rigid, and, if necessary, they may be elastically mounted together with the electrometer valve and input resistor. Often the latter may be conveniently mounted inside the collector, as in Fig. 7, while some of the smaller electrometers can be stowed inside the guard-ring or an extension provided thereon for the purpose.

Geiger Counters

We now pass on to counters operating in the Geiger region DE of Fig. 4. In this type we are interested in counting the output voltage pulses due to the arrival in the counter of individual particles, and the operation is quite different from that of the ionisation chamber. The construction is, again, normally concentric, but the central cylinder is made of wire of the smallest practical diameter in order to make the field intensity as high as possible near the wire. The gas filling may be one of two types which give vastly different characteristics to the counter, and these will be considered separately. The first type is a simple gas at about 10 cm. Hg. pressure (Argon is a common choice), giving what is known as an externally quenched, or non-self-quenched counter.

The non-self-quenched counter

The anode is connected via a resistance to a source of D.C. of about 1-2 KV. Let us now see what happens when an initial ionising event occurs in the counter due to the arrival of a particle. A free electron liberated by this event is accelerated toward the anode. The operating conditions in these counters are such that the electron acquires enough energy to produce further ionisation when in the high field region near the wire, and here an avalanche is formed in the manner previously described. Not all the ionisation produced arises directly, some is the result of indirect processes. For example, while yet some distance from the wire, an electron may gain enough energy to excite, but not ionise, a gas atom. This atom shortly returns to the ground state, emitting a photon, which may give rise to a photo-electron on interaction with the cathode wall. This electron now produces further ionisation, and so on. Since most of the ionisation occurs near the anode, the electrons, with their high mobility, are rapidly collected, leaving a positive ion sheath around the anode. The positive ions move out more slowly toward the cathode, and this action is equivalent to a steady increase in the effective diameter of the anode, as a result of which the field intensity, given by Equation 3, falls off until it can no longer support the formation of further avalanches, and the discharge ceases. The ions are then collected, in a time of the order of 10^{-4} sec., while the separation of charge is recorded as a voltage pulse across the series resistor.

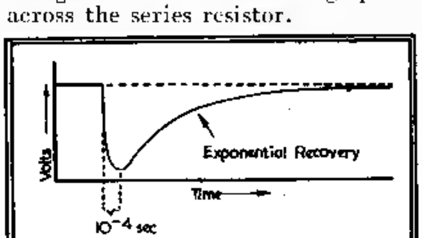


Fig. 9. Form of Geiger counter output pulse

This pulse is of the form shown in Fig. 9; a sharp fall in potential followed by an exponential rise governed by the capacitance of the system and the series resistance.

As the positive ions closely approach the cathode surface, the work function of the latter is overcome by the intense field, and electrons are emitted.[8] These neutralise the ions, but, since the ionisation potential of the simple gas atom normally exceeds the cathode work function, the neutral atom formed possesses the difference energy, i.e., it is excited. On return to the ground state a photon is emitted: this may produce a photoelectron from the gas or the cathode, which in turn may start a fresh discharge if the counter voltage has returned to normal. To prevent this we must use what is described as an external quenching device. The two principle devices used are, first, a multivibrator circuit which reduces the counter potential by several hundred volts after each pulse, and secondly, a very high series resistor (10^9-10^{10} ohms) so that the output pulse itself provides the required drop in potential. In any case, the potential must be kept down until all the ions are completely collected and the counter is again stable.

This means that the non-self-quenched counter is unsuitable for high counting speeds, and cannot distinguish between the closely spaced arrival of particles even if these are only infrequent events, or, in other words, it has poor resolution.

An improvement in this respect results from the use of the self-quenched counter, whose action will be described next.

The Self-quenched Counter

This second type of Geiger Counter is obtained by adding to the simple gas used in the first type above about 10 per cent of a polyatomic vapour, nearly always organic, for example ethyl alcohol. The molecules of such a vapour exhibit, in addition to the electronic excitation levels already described, a series of other energy levels due to quantised increases in the energy of vibration and rotation of the molecules. With each electronic energy level is associated a series of vibrational levels, and with each of the latter is associated a series of rotational levels. This property causes a modification of the counter action. First, during the avalanche few photoelectrons are formed as in the non-self-quenched type, since photons emitted from the simple gas (often called the vehicular gas) are readily absorbed by the complex molecules, which are thereby excited to higher vibrational and rotational levels. The probable time for which a complex molecule remains excited is large compared with the probable time which elapses before it dissociates into fragments, dissipating in kinetic energy the energy of excitation, so that few photons arrive at the cathode. These will be negligible if the photoelectric efficiency of the cathode is low, which is desirable. The discharge is formed near the anode as before, and shows little tendency to spread radially, since few photoelectrons are formed outside the positive ion sheath; instead, it spreads laterally until stopped by field discontinuities, usually at the counter ends. The field is reduced as before by the ion sheath, and the discharge stops. As the sheath moves out toward the cathode, there is a transfer of charge from the simple gas ions to the complex molecules, as the result of collisions, since the latter have the lower ionisation potentials (See Table 1). This low ionisation potential is one of the criteria for the quenching gas. By the time the cathode is reached, practically all the charge resides on complex ions only. Once more electrons are drawn out of the wall and neutralise the complex ions to form excited neutral atoms. As indicated above, these in general dissociate before they are de-excited, so that there is no photon emission and no photoelectrons are formed. Consequently, there are no spurious avalanches, and the voltage may be reapplied to the counter as soon as the discharge is over. From the instant of breakdown to the time when the ion sheath is far enough away from the anode for the field near the wire to have reached operating condition again there elapses about 10^{-4} sec., during which time a particle entering cannot initiate a count. This interval is the "dead-time" for the counter, and is not a reliably fixed quantity, so that the usual procedure again is to use some external circuit to shut down the counter for a slightly longer, but accurately known, time, thus fixing one important experimental condition.

After the dead-time another 10^{-4} sec. (approx.) elapses before all the ions are collected. During this period an entering particle gives a smaller pulse than normal. The sorting out of such pulses is done when desired by the use of amplitude discriminators in the counting device (scaler) which usually follows the Geiger counter.

In actual practice the quenching obtained by the use of the complex gas is not perfect, and spurious counts are of the order of a few per cent.[5]

Effect of Negative Ions

If the counter contains a gas which readily forms negative ions (eg., oxygen), these will be accelerated toward the anode. However, their mobilities are of the same order as those of the positive ions, so that they are likely to arrive near the anode wire after the main count has taken place and after the dead-time has elapsed. In the high field region they may then acquire enough energy to start a new avalanche, or may deionise, an electron thus liberated then provoking a fresh discharge, which will be registered as a spurious count. Any gas with a high electron affinity should therefore be excluded from these counters. This applies to air, on account of its oxygen content.

Voltage Characteristics of Geiger Counters

If a Geiger counter is subjected to a constant irradiation while the voltage across it is slowly raised, this voltage being plotted against the number of counts recorded in unit time, one obtains a curve of the type shown in Fig. 10. It will be

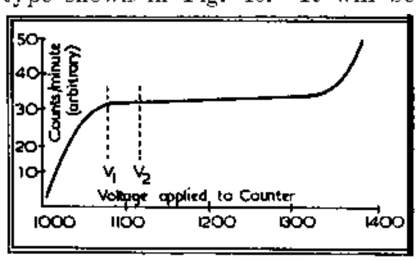


Fig. 10. Voltage characteristic of a Geiger counter

seen that over a wide range of voltage above V_1, the starting potential, there is a "plateau" where the number of counts is almost constant. The reason for the existence of the plateau, expressed in general terms, is that, over this range of applied voltage, every pulse depresses the counter field below threshold, so ensuring cessation of discharge and correct counting. The length of the plateau is thus a function of pulse size, and gases with high specific ionisations such as Hydrogen and Argon will give longer plateaux than gases of low specific ionisation under the same conditions. The specific ionisation of a gas is the number of ion-pairs produced per cm. length of track by the particle in question in traversing the gas at 1 atmosphere pressure. Hence, for a particle traversing x cms. of gas at pressure p, the specific ionisation of the gas being i, the total number of ion-pairs produced will be xip. It follows that increasing the gas pressure will also lengthen the plateau, but this unfortunately raises the starting potential, the latter being proportional, to a first approximation, to p.

By a suitable choice of quenching gas the plateau may be made flat as well as of reasonable length, and a frequent choice for the gas mixture is ethyl alcohol (about 10 per cent) and Argon at 10 cm. pressure or thereabouts.

Output and Life of Geiger Counter

The existence of a plateau region means that the counter can be operated with an output pulse height independent of the initial ionisation, and also that the pulse height will not vary with small changes in applied voltage, so that supply stabilisation is not impossibly critical. A supply constant to $\pm$ 1 per cent is sufficient for most purposes. The output pulse will usually lie in the region of 1-100V, and is made large by increasing the applied voltage as far as the plateau allows, and by reducing the capacitance of the counter, plus any associated circuits.

It is not usual to employ the first alternative, however, since the life of a counter is a function of the applied voltage. The reason is that in every discharge a number of complex quenching molecules are dissociated and this number rises with applied voltage. In many cases the complex molecules are chosen so that the fragments are themselves effective as quenching agents, but eventually the counter becomes useless as these in turn are broken down.[10,11] The number of counts to be expected before this happens is of the order of $10^8 - 10^9$, according to the nature and amount of the quenching gas. The usual operating point is round about V_2 in Fig. 10.

Thanks are due to Messrs. E. K. Cole Ltd. (Electronics Division) for permission to publish this article.

Appendix

We require to find the total energy (kinetic plus potential) of the electron in the Hydrogen atom, assuming circular orbits and quantised angular momentum.

Symbols Used

- c Velocity of light.
- e Electronic charge.
- m Mass of electron.
- h Planck's constant.
- λ Wavelength of emitted photon.
- ν Frequency of emitted photon.
- n Positive integer—the principal quantum number.
- r Radius of orbit.
- ω Angular velocity of electron.
- Z Atomic number.

For each quantised energy state we have:—

$$m\omega r^2 = \frac{nh}{2\pi} \quad \ldots\ldots\ldots\ldots \quad (1)$$

The kinetic energy of the electron is:—

$$E_k = 1/2\ m\omega^2 r^2 \quad \ldots\ldots\ldots\ldots \quad (2)$$

Equating the electrostatic force of attraction, given by Coulomb's Law, and the centrifugal force:—

$$\frac{Ze^2}{r^2} = m\omega^2 r \quad \ldots\ldots\ldots\ldots \quad (3)$$

Combining (1), (2) and (3), eliminating ω and r:—

$$E_k = \frac{2\pi^2 Z^2 e^4 m}{n^2 h^2}$$

TABLE I

	Ionisation Potential (volts)	First Excitation Potential (volts)
Acetone	10.1	—
Ammonia ...	10.5	—
Argon	15.7	11.6
Carbon Dioxide	14.4	—
Ethyl Alcohol ...	11.3	—
Helium	24.5	20.5
Hydrogen (Atomic) ...	13.5	10.2
Hydrogen (Gas)	15.4	11.5
Methane	14.4	—
Neon	21.5	16.6
Nitrogen ...	15.5	6.1
Oxygen	12.5	6.0

Some typical ionisation and excitation potentials.

The figures are taken from S. C. Brown: "Nucleonics" 2, No. 6, 10 June, 1948.

The potential energy of the electron is given by:—

$$E_p = \frac{-Ze^2}{r}$$
$$= -m\omega^2 r^2 \text{ [from (3)]}$$
$$= -2E_k$$

Therefore the total energy E $(= E_p + E_k) = -E_k$

$$= -\frac{2\pi^2 Z^2 e^4 m}{n^2 h^2} \quad \ldots\ldots\ldots\ldots \quad (4)$$

For a transition from an orbit in which $n = n_2$ to a second in which $n = n_1$, we have for the energy of the emitted photon:—

$$h\nu = \triangle E$$

$$= \frac{2\pi^2 Z^2 e^4 m}{h^2}\left\{\frac{1}{n_1^2} - \frac{1}{n_2^2}\right\}$$

$$\text{or } 1/\lambda = \nu/c = \frac{2\pi^2 Z^2 e^4 m}{h^3 c}\left\{\frac{1}{n_1^2} - \frac{1}{n_2^2}\right\}$$

Evaluating (4) for the ground state of the hydrogen atom leads to a value of 13.6 eV. for the total energy. Thus the ionisation potential is 13.6 volts, which is in good agreement with the experimental value of 13.5 volts.

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For a more detailed bibliography of Geiger Counters *see* M. Healea: *Nucleonics 1*, No. 4, 68, 1947.

H.T. SUPPLY FOR TELEVISION RECEIVERS

By C. H. BANTHORPE *

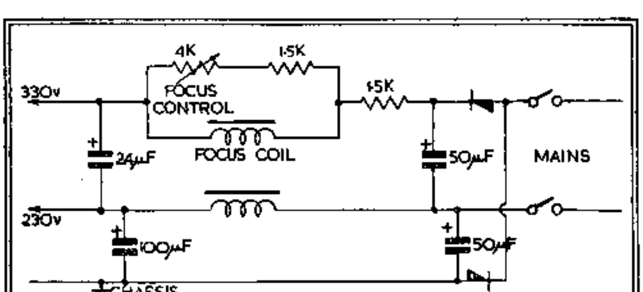
In many television receivers, the H.T. supply must provide approximately 230 volts for vision and sound valves, and up to 330 volts for time bases and anode 1 of the C.R.T., if a tetrode.

These voltages can be produced in a number of ways, but one used by the writer is economical, kind to components, and has no H.T. mains transformer, and can thus be used in compact equipment without magnetic fields, which might be a source of trouble.

To get the higher voltages without a step-up transformer requires some form of voltage doubler, and the type chosen has several advantages and one disadvantage. Firstly, the lower voltage, at high current, can be obtained without wasteful voltage dropping in resistors, which dissipate many watts of heat; always a nuisance in compact equipment. The second advantage is that the voltage across any electrolytic can never exceed the peak voltage of the mains, approximately 325 volts, instead of the 500 volts or so from a 350 volt supply, and this allows higher value capacitors to be used for a given price, or cheaper capacitors for a given capacitance. The third advantage is that the D.C. through the choke is that of the 230 volt line only, and therefore for a given price, more inductance can be obtained, or for a given inductance, a cheaper component can be made.

A disadvantage of a transformerless set is that the mains are connected to the receiver chassis and safety precautions must be taken to prevent shocks. In this supply neither side is directly joined to the mains, but the same precautions must be taken. The circuit shows one such circuit used successfully in production. The capacitors are contained in two cans and are made by B.E.C. One is a 50-50-100 μF 275 V wkg., C.E.15620, and the other is a 24 μF 275 V wkg., C.E.15621. As the 330 V line feeds anodes only, the current through the focus coil is partially stabilised and variations due to temperature changes of the coil are not troublesome.

* Central Equipment, Ltd.



This voltage-doubler circuit gives transformer-less H.T. for sound and vision receivers and time bases

Television in Birmingham

(Many readers of *Electronic Engineering* will be aware of the recent demonstration of Television Signals in Birmingham on Nov. 3, 1949, by means of the Radio Relay Link between Museum Telephone Exchange, London and Telephone House, Birmingham.

The following is a brief description, with illustrations, of the Relay Link based on information supplied by the General Electric Co. Ltd., who designed, manufactured and installed the system to Post Office specifications.)

THE London-Birmingham Radio Television Link marks a great advance in television transmission technique, and places Britain right in the fore-front of television development. Indeed, it can now be fairly claimed that nowhere else in the world does there exist a television relay system so technically advanced for continuous public service. The many new inventions embodied in the Link and the invaluable information gained during its construction will be of the greatest value in designing radio links for other telecommunication projects, such as multi-channel telephone, teleprinter and picture telegraph systems. Even greater possibilities can be envisaged in their use in establishing communications over desert country, river crossings and even in jungle country, where the nature of the terrain renders virtually impossible the use of more normal modes of communication.

The Link is suitable for the transmission of 405 line, 50 frames/second, television signals of the waveform transmitted at present by the B.B.C. from Alexandra Palace and to be transmitted from Sutton Coldfield. The contract issued by the Post Office in May, 1947, was for the interconnexion of London and Birmingham, but required that the system should be so designed that it could be extended up to 400 miles.

When completed, the radio-television Link will provide for simultaneous two-way transmission of television signals between the two cities. At the present stage a reversible link is installed, so that transmission in either direction can be obtained as desired. This reversible service has been provided with just over 60 per cent of the complete radio equipment and without the erection of the final special repeater-station towers. The aerials are erected on temporary masts and the equipment is installed in the buildings at the foot of the masts. For the two-way link the radio equipment will be installed in special cabins at the tops of the repeater station towers. The present reversible system uses two frequencies of transmission: 870 and 890 Mc/s. A station which receives on 870 Mc/s. transmits on 890 Mc/s. and vice versa. These two frequencies are used for either direction of transmission with the reversible link and will eventually be used for one direction of the two-way link, 917 and 937 Mc/s. being used in similar fashion for the other direction.

The use of these frequencies necessitates optical paths between transmitters and receivers for satisfactory and consistent performance. It has therefore been necessary to use repeater stations at Harrow, Dunstable, Blackdown and Rowley Regis.

The television signal is transmitted over the television link by frequency-modulation of the 900 Mc/s. carrier; this being achieved at a terminal station in two steps. The vision-frequency signal is used to frequency-modulate an oscillator between 32.5 and 35.5 Mc/s. and the modulated oscillation is amplified and applied, together with the output of a 900 Mc/s. generating chain, to the final stage of the transmitter. In this stage, frequencies are produced which differ from that of the R.F. generating chain by amounts equal to the frequency of the modulated oscillation. Both these signals, the frequency of one of which is above, and the other below, that of the R.F. generating chain, are frequency-modulated by the vision-frequency signal to the same extent as was the original 34 Mc/s. oscillator. One of these frequency-modulated carriers is selected by filters and is the signal transmitted.

At a repeater station, the received signal is heterodyned by a local oscillator to give a difference frequency of 34 Mc/s. This I.F. signal is amplified, and the transmission process is repeated. The transmitted signal is not demodulated to vision-frequency until the receiving terminal is reached. By the use of this system the difficulties of amplifier design and operation at low vision frequencies are avoided.

The transmitting frequency at a repeater station cannot be the same as the receiving frequency, since the receiver would then receive power from the local transmitter as well as from the previous station. For this reason the frequency of the receiver local oscillator cannot be the same as that of the transmitter master-oscillator. Therefore, at a repeater station the local oscillator frequency is derived from part of the transmitter master-oscillator output by heterodyning it with the output of a crystal controlled oscillator whose frequency is equal to the difference between the received and transmitted frequencies. By arranging that the local and master oscillator frequencies are each above, or each below, the received and transmitted frequencies respectively the transmitted frequency is made independent of the drift of the station master oscillator and is affected only by the small drift of the crystal controlled oscillator. Since only two frequencies are used for one channel the shift frequency is the same at all repeater stations, and is alternately added to or subtracted from the station master oscillator frequency.

The power transmitted from each station is of the order of 10 watts, and the received power for free space propagation over a 40-mile path is just over a microwatt. Thus the gain of a repeater station is 70 db.

The vision-frequency signal is fed into the terminal modulator from Post Office equipment via a coaxial cable. The output of the terminal

London–Birmingham

Terminal and Repeater

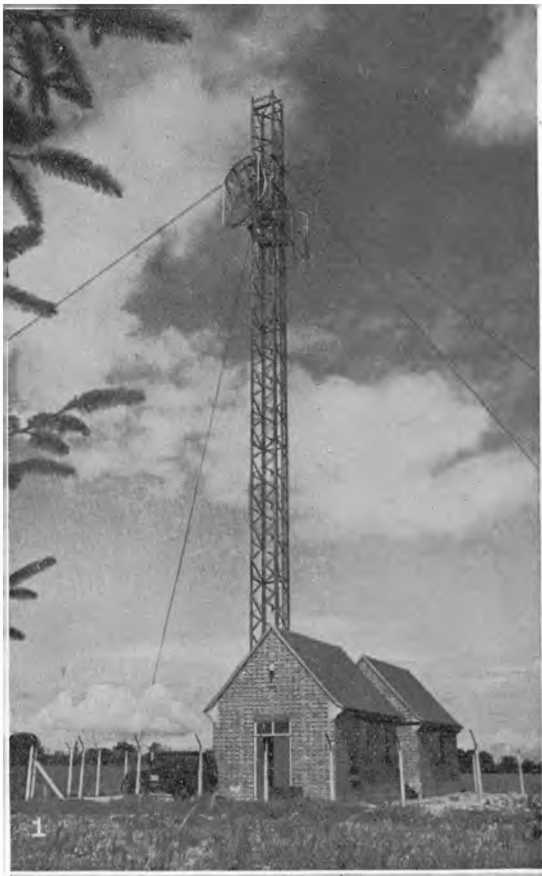


Fig. 1.—Exterior view of Dunstable repeater station, showing aerial arrays erected on a temporary mast. The buildings at the foot of the tower house the standby generator equipment, the transmitter-receiver power and monitoring equipment.

Fig. 2.—The terminal aerial array at Telephone House, Birmingham. From Telephone House the vision signals are carried by coaxial cable to the B.B.C.'s transmitter at Sutton Coldfield

Fig. 3.—Model of a final repeater station, showing special cabin at the top of the mast to house the transmitter-receiver and equipment in the final simultaneous two-way transmission project.

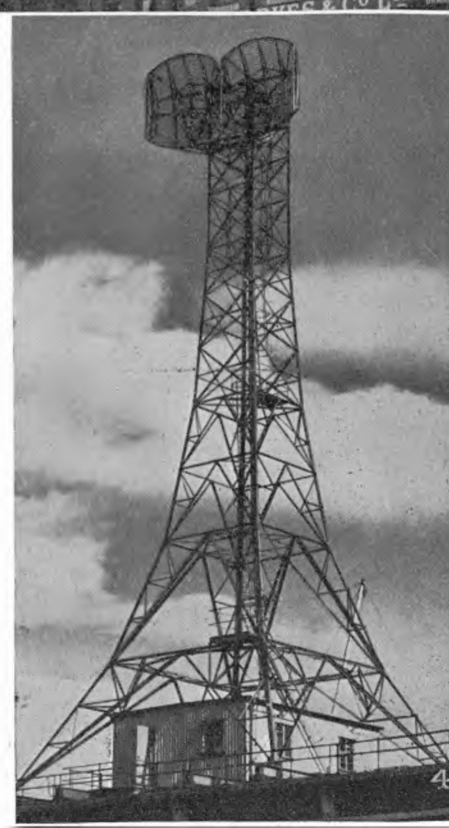
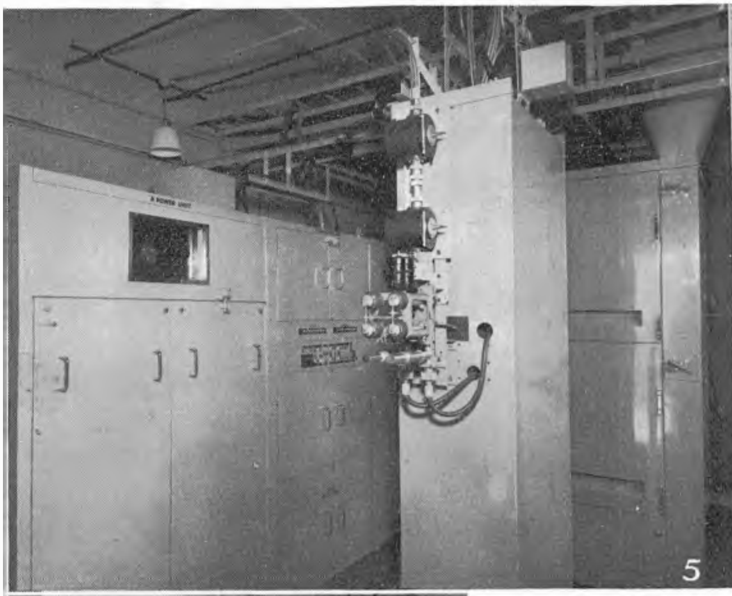
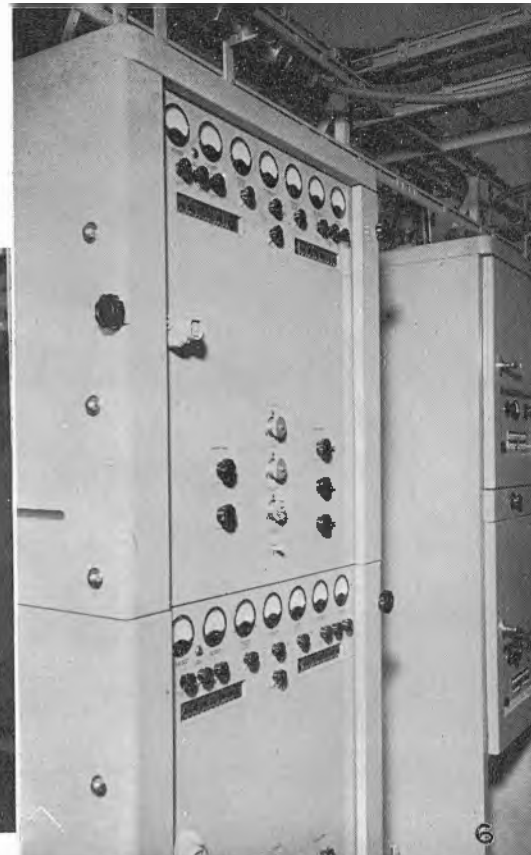


Fig. 4.—The terminal aerial array at Museum Exchange, London.

Television Link

Station Equipment





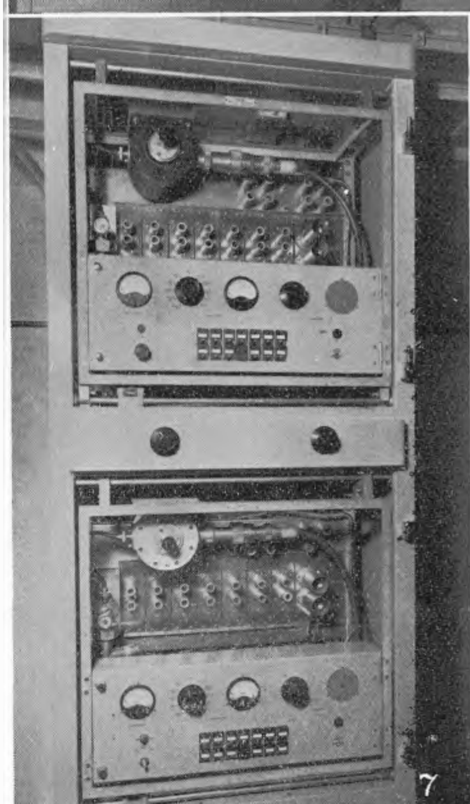


Fig. 5.—Equipment building at Blackdown repeater station, showing contactless R.F. *switch mounted on the side of the receiver with resonant cavity filters above.*

Fig. 6.—Exterior of transmitter cabinets, showing alternative transmitters.

Fig. 7.—Interior view of receivers.

Fig. 8.—Typical R.F. *transmitter amplifier, using an* ACT 25 *valve.*

modulator is a frequency-modulated 34 Mc/s. signal which is applied to the terminal transmitter, and the R.F. output of the transmitter is taken through output filters and an output monitor to the transmitting aerial. This consists of a paraboloid reflector formed from light-alloy tubes and energised by a coaxial-line fed dipole and parasitic reflector. The full diameter of the paraboloid is 14 ft., but its horizontal aperture has been cut to 10 ft. with very little loss of gain (since horizontal polarisation is used). The gain of the aerial is 27.5 db. with reference to that of a half-wave dipole. Coaxial cables are used throughout as feeders for the 900 Mc/s. energy.

Duplicate signal channel equipment and power units with changeover switching are provided to maintain the operation of the link in the event of a failure in the working equipment. The equipment which is not in use is kept warmed-up in a standby condition, so that it is ready for immediate operation. The aerial system and transmitter output filters are not duplicated, and therefore a radio-frequency switch is provided in the feeder between the transmitter and its output filters.

Changeover switching between the power units and the signal channel equipment is so arranged that each channel equipment can be connected to either power unit.

At repeater stations, the R.F. input from the receiving aerial is fed through the receiver input filter and an R.F. switch to the selected receiver. The transmitter feeder arrangement is the same as at a terminal transmitting station. Duplicate equipment is provided as at a terminal station, the receiver and transmitter being considered for switching as one unit. At a terminal receiving station, the feeder arrangement is the same as for the receiver at a repeater station.

Control and monitoring equipment is provided at each station by which all the normal operations for that station can be carried out. All the radio stations and the control points are linked by a control telephone which has selective ringing but a common speech channel for all the stations.

In addition to the main signal channel equipment, comprehensive test equipment is being supplied for the assessment of the overall vision-frequency response of the complete system from terminal to terminal. In addition, a monitor for the transmitted picture and waveform is being supplied for each control point, each radio terminal and each repeater station. Special radio-frequency testing equipment is also being provided for each radio station.

The system makes use of a range of advanced techniques in valve and circuit design, and the radio frequency equipment is based upon disk-seal triodes type DET 24 and ACT 25 which are used in coaxial-line circuit equipment. Such circuits are markedly different from circuits performing similar functions at lower frequencies. Each tuned circuit is essentially a length of coaxial transmission line, and a particular feature of the circuits used in the Television Link is that they have been designed for reliable and stable operation over long periods by elimination of sliding contacts and by robust construction.

The transmitter consists of a master oscillator (DET 24) stage, a first R.F. amplifier (DET 24) stage, a second R.F. *amplifier* (ACT 25) stage and a modulated (ACT 25) or frequency-changer stage. In addition, there is a (DET 24) frequency-shifter stage for the derivation of local-oscillator power, together with its associated 20 Mc/s. crystal-controlled shift-frequency generator. The transmitter is designed for normal operation at full output with a drive of 4 volts peak-to-peak of intermediate-frequency signal. This I.F. signal is amplified to a level sufficient fully to modulate the end stage of the transmitter in a wide-band amplifier using A1820 and KT67 valves.

The receiver uses a silicon crystal as frequency-changer, local oscillator power being fed from the transmitter via a filter consisting of two cavity resonators, which removes unwanted components generated in the frequency-shifter. The receiver I.F. amplifier consists of two stages each using a pair of E1714 low-noise triodes, followed by three automatic gain-controlled stages each using a pair of Z77 pentodes, and a further two stages each using a pair of Z77 valves, the output stage being a cathode-follower consisting of a pair of Osram valves.

The radio-frequency filters used in the system are of two main types, i.e., band-pass filters comprising pairs of coupled resonant cavities, and special band elimination filters, which are based on the properties of multiple resonant lengths of transmission lines. Similar resonant line principles are made use of in the contactless R.F. switch, which is used for switching over to standby receivers and transmitters.

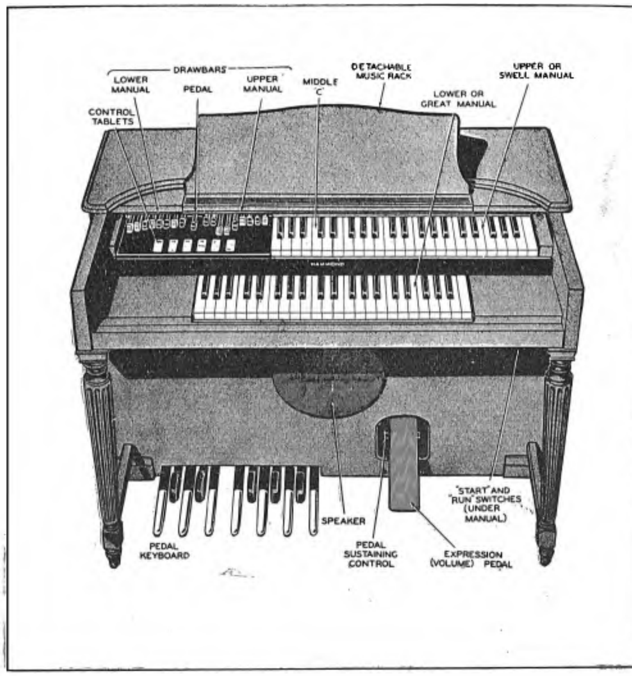
For the reversible link which is now being operated, only two aerials are provided at each repeater station, and since the transmitter and receiver are both connected to each aerial, there is a physical path from transmitter to receiver. The change of direction of transmission is produced by the operation of further contactless-switches, and the receiver is protected from signals from the transmitter by the combination of line and cavity filters.

In conclusion, it is worthwhile to record the history of the system. The Post Office specification was issued in November, 1946, and extensive field-trials to prove the practicability of the system were carried out by a small research team from the G.E.C. Research Laboratories during December, 1946, and January, 1947, at the depth of the most severe winter for many years. The building up of the team at the Wembley Research Laboratories began immediately, and the design of the system was commenced. Just over a year later, in June, 1948, a successful demonstration was given of transmission of 405-line television signals, using apparatus typical of that which had been developed. This followed upon the conclusion of extensive field-testing of the route which had been finally chosen. The next year was devoted to the elimination of teething troubles and to the engineering of the equipment. The first transmission of television signals took place on August 31, 1949, from a temporary terminal station at the Wembley Research Laboratories, through Harrow Weald, Dunstable, Blackdown and Turners Hill Repeater Stations to the Telephone House Terminal Station at Birmingham. This transmission included pictures broadcast by the B.B.C. from Alexandra Palace and received at Wembley for relaying through the Link.

The Hammond Spinet

A New Electrical Musical Instrument

By ALAN DOUGLAS



THE Hammond organ and its electro-mechanical tone generating system is well known in this country. Since the end of the war, a number of improvements have been made to this instrument, but so far the exchange position has prevented their importation. Recently the Hammond Instrument Company has introduced a simplified organesque type of instrument for use in the home. There are many ingenious features in the design.

The appearance of the console is shown above. It will be seen that there are two manuals, each of 3½ octaves compass, which overlap. There is also a series of 12 pedal keys, permanently attached to the instrument. One set of harmonic drawbars controlling eight harmonics provides a variable tonal set-up for the lower manual, while one set of nine drawbars supplies the upper manual. In this organ, harmonics up to the 12th are controlled by the drawbars. A single drawbar regulates the volume of the pedals, which are of 16 ft. pitch only. Fig. 1 shows the controls.

One of the major criticisms of previous Hammond instruments was the abrupt attack and decay of the sound. This feature is still evident on the manuals, though it can be prevented by correct fingering. The pedal department in this instrument has, however, a number of controls by which the rate of attack and decay can be varied.

In previous instruments, the vibrato or tremulant effect was produced by a rotating interrupter, which varied the volume but not the pitch. This is not comparable with the effect from a pipe organ, in which both the frequency and volume are modulated.

In the Spinet model, there is a phase shift network which alters the frequency in a continuous fashion. By means of an ingenious circuit fixed phase differences may also be produced for various applied frequencies; so that an added subtlety of tone can be obtained by proper manipulation. This device replaces the chorus generator on all models.

The amplifying and loudspeaking equipment is contained in the console, so that the entire system is portable and of very small size. The name of the instrument is derived from a type of piano very popular in the U.S.A., known as a spinet; it is intermediate in size between a minipiano and a small upright piano.

The generating system of this organ employs 86 rotating iron wheels, as against 91 in the standard organs. Of these, the lowest 12 are used for the pedals only, and have a special contour which generates a pre-formed wave. There is no harmonic mixing from these wheels.

The manual generators run from 18 to 91; thus 13 to 17 are omitted. This range covers from F = 87.307 c/s to B = 5919.9 c/s, there being, in effect, an extended F octave in the bass of the lower manual and an extended C octave in the treble of the upper manual.

Most of the generators have a tuned filter across their outputs, this now being a series resonant transformer in place of the centre-tapped choke previously used. The manual generators have the familiar contour designed to produce a sinusoidal wave as nearly as possible.

Each manual playing key closes the usual set of eight or nine contacts, thus introducing the full series of generators to the mixing controls, but the pedal department is interesting. Only one pedal key at a time may be depressed. Fig. 2 shows the pedal amplifier. When a key is operated, a contact selects the correct generator and couples it to the grid of $V7$. This valve is, however, biased to cut-off Later in the movement of the pedal, a "pedal keying contact" (common to all pedals) closes. This discharges $C50$ and allows the note to sound.

If the pedal attack control is at "normal," a single resistor discharges $C50$; this allows a rapid attack. If the control is at "slow," an additional resistor $R45$ is introduced, so that the delay in speaking is increased.

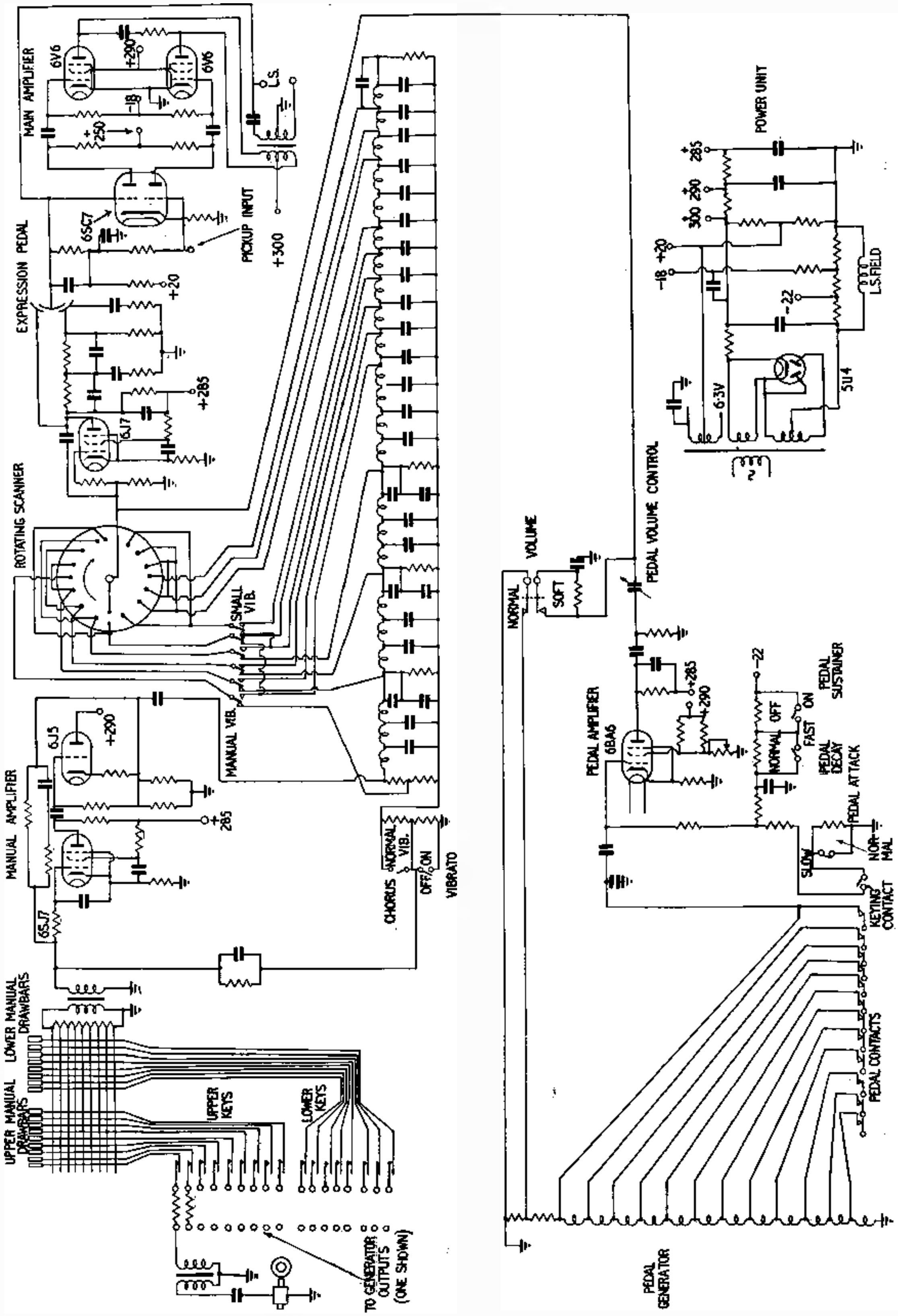


Fig. 3. Simplified circuit of the complete instrument

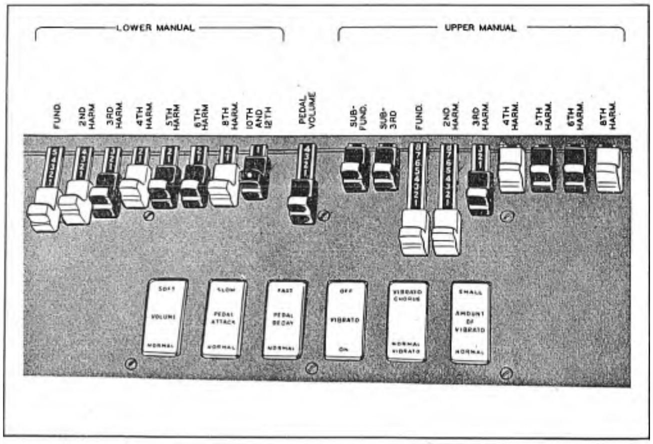


Fig. 1. Drawbars and control tablets

Now when a pedal key is released, the keying contact opens, and this allows cut-off bias to be applied to *V7*. With the "decay" control at "fast," *R52* charges *C50* in a short time. When set at "normal," additional resistance still further increases the charging time. There is a sustaining control on the expression pedal, and if this is used, still further resistance is introduced, so that the note sounds for quite a long time.

To prevent a pedal note from sounding when the organ is first switched on, a resistor in series with the heater of *V7* delays the warming-up period until bias has been applied to this valve.

The foregoing amplifier is, of course, a pre-amplifier before the main section. The volume of the pedal amplifier is adjusted (by the drawbar) by altering the capacitance of a small variable capacitor. It will be recalled that this method is used to control the volume of the "Novachord," also a Hammond product.

To turn now to the other novel feature. The comparatively limited tonal resources of the instrument at any one time suggest that an effective vibrato would enhance its appeal. The Hammond vibrato is a frequency shifting device consisting of a number of low-pass filter sections in series, with a capacitance scanner which is applied continuously up and down the line by means of a rotating capacitor.

Waves fed into the line are retarded in phase in each section of the line, the amount per section being proportional to frequency. As the scanner travels along the line, it alternatively raises and lowers the output frequency, the average remaining equal to the input frequency. There are 16 sets of stationary plates on the scanner and one rotating set, which meshes with each stationary set once in each revolution.

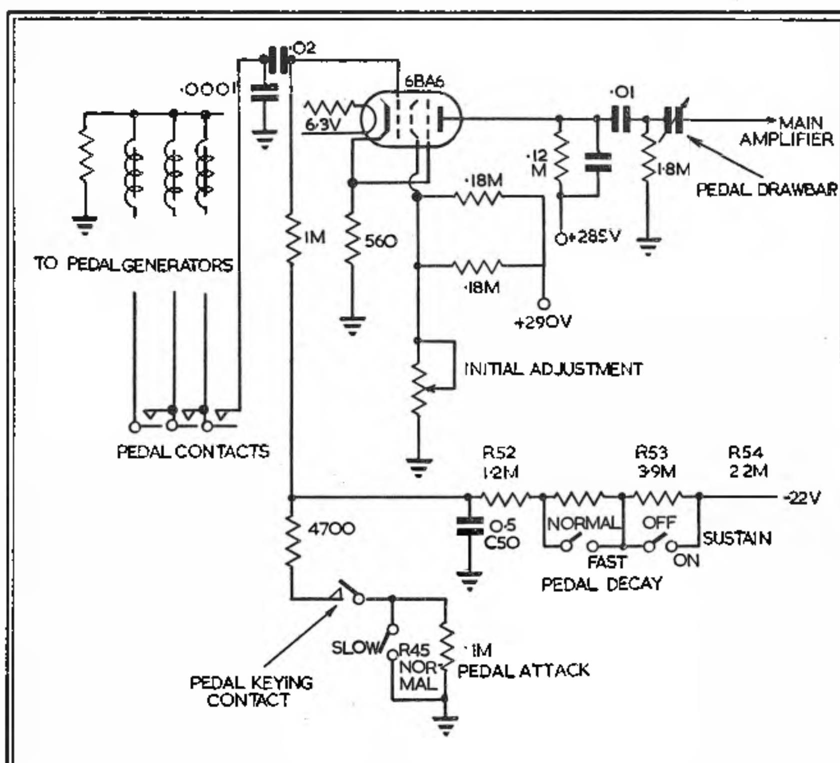
The depth of the vibrato can be controlled by causing only parts of the line network to be scanned; the smaller the number of sections connected, the smaller the degree of vibrato. An ingenious arrangement allows part of the generator signals to be passed through the line delay, and part directly to the amplifier; this gives a certain degree of richness to the sound, producing a chorus effect.

The vibrato is turned off by placing a very high resistance in series with the line. Practically all the signal appears across this resistor and the vibrato effect is eliminated.

A simplified circuit diagram, in which all the foregoing elements can be seen, is shown in Fig. 3 opposite. It will be noted that the smoothing of the power supply is economically carried out: to assist in reducing hum due to heater emission, the centre tap of the amplifier heater transformer winding is connected to a positive potential.

The author was able to play this instrument on several occasions when in the U.S.A. recently, and found it most interesting and colourful. Although reduced to the bare minimum from a design point of view, it is tonally much superior to the original Hammond organs. It is not suitable for normal organ replacement, as registration is slow owing to the absence of pre-set tone-colours.

Fig. 2. Pedal amplifier using 6BA6 valve for V7 position



Obstacle Detection Using Ultrasonic Waves in Air

By G. BRADFIELD *

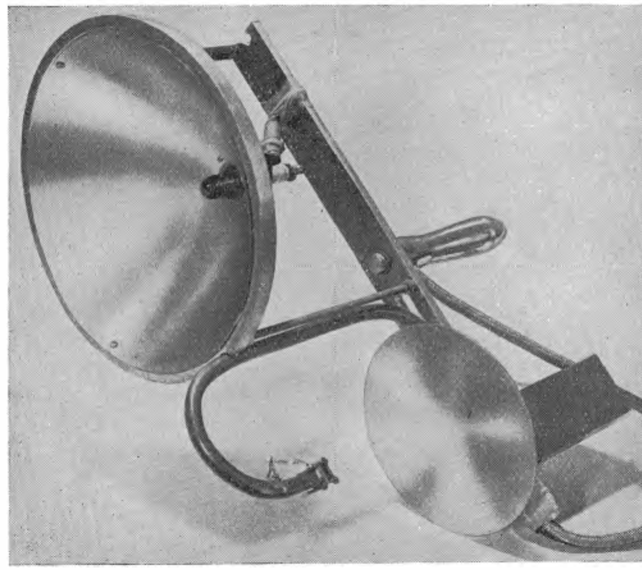


Fig. 1. View of combined transmitting and receiving device

EVERYONE is familiar with the delayed returned sound wave, the echo. Its presence is readily apparent when the travel time of the sound wave between transmission and reception by the ear is about 1/10th second, corresponding to a total distance of 100 ft. or more, but, with practice, aural perception of an echo is possible for much shorter times and distances. Clearly electronic equipment could be devised which would surpass the ear when reception and demonstration of such short time intervals are of interest. These considerations lead to the possibility of an obstacle detector using airborne waves. Warning of the close proximity of obstacles is of first importance to the user of any obstacle detector, but directivity in such a device is also essential. The ear and conveniently sized sound sources are not very good for directivity until the pitch of the sound becomes quite high. The use of audible waves for obstacle detection, however, has two serious disadvantages. Firstly, they may be masked by the common noises of our surroundings and, secondly, audible signals may themselves be obtrusive and disturbing. These two disadvantages are at once eliminated if ultrasonic frequencies are used and these bring, furthermore, the positive advantage that ample directivity is readily achieved by their use.

It is only fair to point out that various attempts have been made in the U.S.A. and in this country to use ultrasonic guiding devices, but so far without much success. Few data have been published on which to judge of the possibilities of such devices for practical applications. It is the purpose of this article to do something to fill this gap.

The equipment used for this investigation was not the most suitable from every point of view; indeed, much of it had been designed for quite a different purpose. Although it is believed that the receiver used (of the piezo-electric type) was fairly sensitive for the 50 Kc/s. region, it is recognised that the ultrasonic source employed, an electric spark, was very inefficient. The disadvantage of inefficiency, itself not serious because the acoustic output was quite powerful, was more than offset with this type of source by the ease of generation, by its wide frequency spectrum and by the smallness of its physical dimensions, a feature very favourable for use with focusing mirrors.

Apart from the industrial applications, which were instrumental in directing the author's attention to these problems, two obstacle detecting applications, Blind Man's Aid and Safety-in-Fog device—to assist road transport—are worthy of study and the results obtained in this investigation would appear to provide useful guidance in regard to both of them; but it cannot be too strongly emphasised that it would be very unwise to speculate optimistically concerning either until a great deal more careful work has been done on them. Now to consider these two applications briefly.

The Blind Man's Aid

In the absence of any "artificial eye" for light, which, with the interpreting system necessary to supplement it, seems much too cumbersome an equipment ever to be carried by a blind man, a "radar" technique (i.e., a range-plus-direction technique) seems most promising. Equipment using electromagnetic waves appears to be out of the question, but ultrasonic waves provide a possible answer, though with limitations, some of which will be discussed in this article.

It must be emphasised that even if ultrasonic waves could reveal all the details concerning his surroundings which a blind man needs, and this is by no means the case, a second development of considerable complexity would be required to interpret the data to him; and, finally, a perhaps impossibly difficult development would be needed to reduce the bulk and weight of the equipment to the necessary degree so as to make it not only portable but, above all, inconspicuous.

Putting aside the foregoing considerations, it is certain that a blind man would wish to have warning concerning the following three types of hazard:—

(a) Wall, glass window, lamp post or another person;
(b) Kerb or up-going steps;

* Telecommunications Research Establishment, Ministry of Supply.

(c) Down-going step or flight of steps.

The experiments described herein deal with all of these, or with simulations of them.

Safety-in-Fog to Aid Road Transport

For vehicles, in place of visible light, it is desired to find waves which will penetrate fog, but although these may be either electro-magnetic or mechanical, waves of the former type demand for their generation and detection equipment far more complex than for the latter. In general, a radar technique, using pulses or trains of waves, seems most promising.

The problems encountered are thought to be—

(a) Detect waves reflected from kerbs and walls at the side of the road.

(b) Detect waves reflected from on-coming traffic.

The experiments recorded here show what has been achieved with simple equipment in this way.

Design Considerations for Ultrasonic Transmitters and Receivers for Use in Air

Alternatives to the spark source used in these tests would be magneto-strictive or, and these are more promising, piezo-electric devices. To produce powerful waves in such a weak medium as air, large amplitudes are necessary but the forces involved will be quite small. The double crystal type of piezo-electric element is therefore most suitable. This operates rather like the bi-metallic strip which curls on heating. Two thin "expander" crystals, chosen for polarity so that one expands when the other contracts, can be cemented together and will bend or curl when polarised. Shear cut crystals can also be used in this way.

When we are proposing to use such devices for ranging, although we need to radiate intense waves, we must not store too much vibrational energy in our transmitter or its slow rate of decay will cause serious embarrassment in our task of measuring very short time intervals. We cannot therefore build up a high amplitude by resonance and we are very much limited in output power by breakdown voltage conditions and saturation piezo-electric effects. We have not therefore used piezo-electric transmitting transducers in these tests. For the reasons given, explosions (an electric spark has the nature of an explosion) and modulated air stream devices are to be preferred as sources of intense sound waves; it is believed that worthwhile advances can be made with the latter, especially where frequency- or amplitude-modulated continuous waves are employed for ranging rather than pulses.

For receivers, breakdown voltage and saturation effects are not present to discourage the use of piezo-electric elements and, on account of their good sensitivity and convenience, these devices were used in the experiments to be described.

Choice of Frequency for Ultrasonic Ranging in Air

It can readily be shown that for sonic transmission in fluids between an *extensive* radiator and an *extensive* receiving element, both of circular aperture D:—

$$\frac{P_r}{P_G} = \frac{D^4}{9\lambda^2 d^2}\, exp\left(\frac{2\alpha d}{\lambda^2}\right) \ldots \quad (1)$$

where

P_r is the received electrical signal,

P_G is the generated electrical signal power,

λ is the wavelength,

d is the separation of the radiator and the receiver,

α is an attenuation constant for the fluid under consideration;

it is independent of frequency for all fluids, except those which exhibit relaxation phenomena. The assumption has been made that the transducers are 100 per cent efficient (mechanical/electrical power) and that perfect matching exists between the propagating medium and the transducers.

Where the above holds there is a minimum attenuation at an optimum wavelength of λ_0 which is obtained by differentiation:—

$$\lambda_0 = \sqrt{2\alpha d} \ \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Taking a pessimistic assumption for air, at ordinary temperature α is .0017 if d is in cm.

From this the optimum wavelength λ_0 and frequency for minimum overall attentuation for various distances for the above specified conditions will be as in Table 1:—

Table I

Distance d in feet...	10	20	40	80
Distance d in cm.	305	610	1220	2440
Optimum wave-length λ_0/ in cms.	1.02	1.44	2.04	2.88
Optimum wave-length λ_0/ in inches	0.4	0.57	0.8	1.14
Optimum frequency in Kc/s. ...	33	23	16½	11½

The above equation holds for total reflexion from extensive plane surfaces where the total path is d, while for the more interesting case where the returned signals are from small perfectly scattering objects several wavelengths in extent, the optimum wavelength is the same, but the complete expression for the received electrical power on the above assumption is:—

$$\frac{P_r}{P_G} = \text{constant} \times \frac{D^4 A}{\lambda^2 d_1^{\,4}}\, exp - 4\alpha d_1/\lambda \ \ldots \quad (3)$$

In this expression d_1 is the separation between the common transmitting/receiving position and the scattering object, and A is the effective echoing area of the latter which, in the case of a sphere, is approximately its projected area. In the case of returns from a cluster of small objects, each of which is distinctly smaller than a wavelength, the expression is similar to (3) with change of constant and an increase of the index of λ in the denominator to 6. The optimum wavelength is then approximately halved.

If we are concerned with a distance of say 20 feet from the observer to the object sought, we shall thus, for large objects, expect to find it best to use a frequency of 23 Kc/s. and for clusters of tiny objects 50 Kc/s. In the tests to be described 52 Kc/s. and 110 Kc/s. were used.

Details of Ultrasonic Equipment Used in the Experiments

The combined transmitting and receiving device is shown in the photograph of Fig. 1 and, in some detail, in the sketches of Fig. 2. The spark transmitter had a standard 14 mm. spark plug fixed in it, with the gap at the focus of the 7½ in. diameter paraboloid. The gap itself was a little over one millimetre so that it was short compared with the wavelength used (3 to 7 mm.).

The microphone incorporated a hollow double bimorph (twister-type) Rochelle salt crystal of dimensions 9.5 × 9.5 × 3 mm.; the crystal was of the sensitive, temperature-dependent cut and it had a resonance around 19 Kc/s. It was clamped onto the end of a swan-neck, the latter being lightly packed with cotton-wool; this also served as a shield for the lead going to the CV138 Head Amplifier (see schematic Fig. 3). The crystal was located at the focus of a 5 in. diameter paraboloid and, at 50 Kc/s., the main lobe of its polar diagram approximately filled this aperture.

The spark occurred when the charging of the 0.25µF capacitor from the 6 KV supply via a 1.2 megohm resistor raised the voltage to about 4 KV. The discharge provided a synchronising signal over a 20 pF to 10 K. network (shown in Fig. 3).

The received signal was further amplified by an amplifier having a maximum gain of about 100 db. centred on 52 Kc/s. with an overall band-width of 14 Kc/s., the output

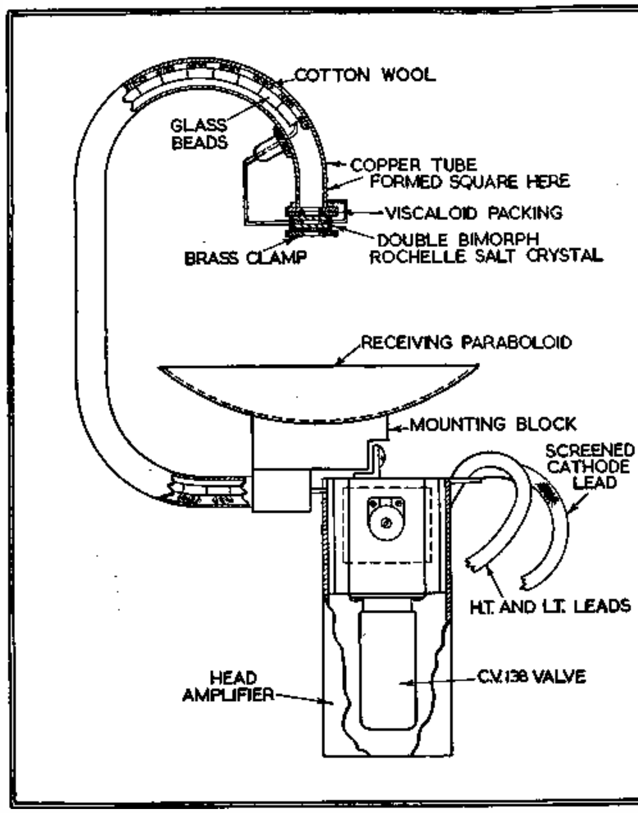


Fig. 2(b) (right). Details of receiver and head amplifier

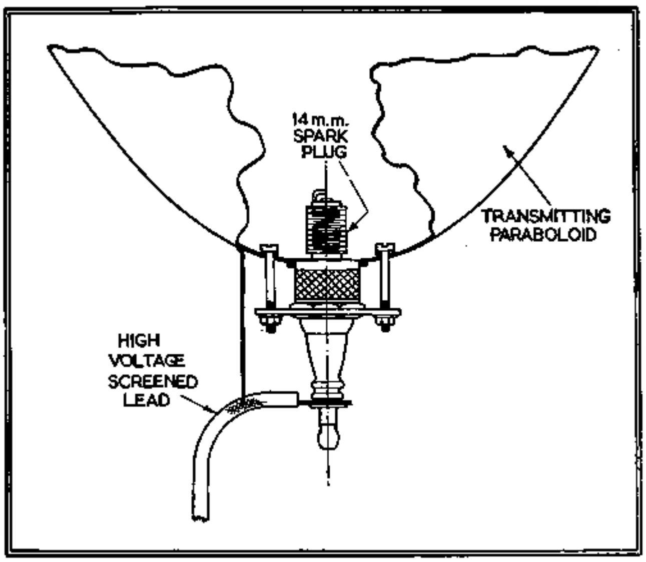


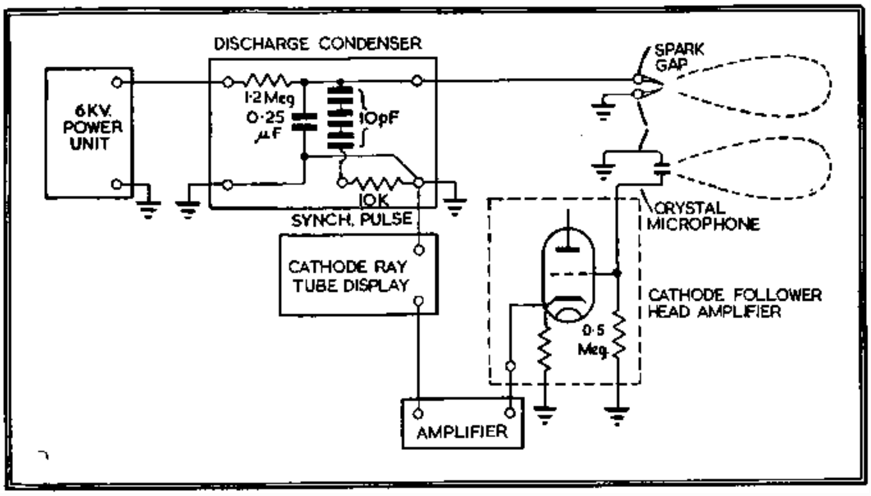
Fig. 2(a) (left). Details of transmitter

being fed to the cathode ray tube display. (See Fig. 3). A 110 Kc/s. amplifier with a bandwidth of about 20 Kc/s. was used for the higher frequency tests. In most of these tests the signal was rectified before the final amplifying stage.

Frequency Kc/s.	Subject	Approx. RMS Voltage on Crystal (capacitance ≃ 250 pF.)	Approx. db. above thermal agitation level
52	Person at 16 feet and wall at about 20 feet	400 µV 1.2 mV (wall)	48 58
52	1 ft. ball at 16 feet and wall at about 20 feet	386 µV 1.46 mV (wall)	48 59
52	Brick (on laboratory floor) to simulate a kerb at 16 feet	430 µV 200 µV	49 42
52	Beam on lip of down-going step	13 µV	18
52	Beam on cinder path at 8 feet	5½ µV	11
110	Beam directed down on cinder path at 8 feet	7.2 µV	13
52	Automobile head-on at 29 feet	110 µV	37
52	Brick (on laboratory floor) at 9 feet	2.5 mV	64
110	Brick (on laboratory floor) at 9 feet	140 µV	39
52	Beam on foot of 3½ in. 3 ft. long steel tube at 9 feet (to simulate lamp post)	1.62 mV	40
52	Cluster of 36 6BA by ½ in. screws at 9 feet	29 µV	25
110	Cluster of 36 6BA by ½ in. screws at 9 feet	14 µV	19
110	Beam on foot of 3½ in. diameter, 3 ft. long steel tube at 9 feet	236 µV	43
52	Teacup at 9 feet on laboratory floor	250 µV	44
110	Teacup at 9 feet on laboratory floor	108 µV	37
52	Beam on foot of 3½ in. diameter, 3 ft. long steel tube at 16ft.	84 µV	35
52	Beam normal on 2 ft. by 15 in. sheet at 8 ft. 4 in.	37 mV	88
110	Beam normal on 2 ft. by 15 in. sheet at 8 ft. 4 in.	790 µV	54
110	1 ft. diameter ball at 16 feet	66 µV	33

Results

Some of the results obtained are summarised in the table opposite, a typical test being shown in Fig. 4. Adjustments to equipment were made in the laboratory, using the ball target to assess the effect of using different types of spark plug and amplifier, to check the alignment of the parabolic reflectors used in the device and the effect of changes in the earthing system in reducing paralysis. At the two frequencies under discussion, 52 and 110 Kc/s., replacement of the spark plug by a spark gap of much more open construction had no marked effect on the signal received. It was found that a great reduction in paralysis could be achieved by completely insulating the earth return of the spark from the earth return of the microphone and by placing a large copper screening can over the back of the spark plug. These are



quite important points in the design. It is also best for the whole of the transmitting paraboloid metal parts to be completely insulated from the main frame.

The spark transmitter conditions were measured. The rate was 3 to 4 a second, the mean feed current was 2.7 mA, the D.C. supply 5.4 KV and the spark occurred at about 4 KV with a peak current of about 500 amps. From these results it would appear that the duration of the spark was 1 to $1\frac{1}{2}$ microseconds.

Tests were carried out in the laboratory to supplement those made out of doors. The effect of a lamp-post target located on tarmac was simulated by standing a $3\frac{1}{2}$ in. diameter 3 ft. long tube on the linoleum of the laboratory floor. Good returns were consistently obtained from its foot with a beam sloping downwards at 20° to 30°, but beam elevation was rather critical for nearly horizontal incidence. Bricks were readily seen since they acted as corner reflectors when on the floor, but to give a good echo their edges needed to be substantially normal to the beam. An object such as a teacup on the floor gave a very good echo. To assess the effect of a degree of roughness on the floor, a cluster of three dozen 6 BA × $\frac{1}{2}$ in. screws were used and gave readily visible returns. When testing at 52 Kc/s. for the magnitude of the reflexion from a large sheet, an experiment was carried out which proved that the active area at 8 ft. 4in. was only about 9 in. in diameter, i.e., 5°.

The amplifiers used were calibrated and approximate values of the peak echoes were made by measurement of the photographs of the oscillograms. Wide variations from these often occur because the orientations of the ultrasonic device and of the subject were quite critical.

Fig. 3 (at top of page). Circuit of combined transmitting and receiving device

Fig. 4 (left). Viewing cinder path and steps

Directivity

The directivity of the combined transmitting and receiving device was very high. Some measurements on the half amplitude widths of a rather similar parabolic reflector with spark plug (transmitter only) are tabulated below:—

Frequency Kc/s	Measured Beam Width	Theoretical Beam Width
20	12½°	10°
40	8°	5°
55	12°	3.6°
75	9°	2.7°
110	3½°	1.8°

The 5 in. receiving parabola has a somewhat larger angle and the combined device has, of course, a directivity characteristic corresponding to the product of those of its two elements.

For specular reflexion from an extensive plane, as is the optical case, a given inclination of the plane is effectively doubled and results in very critical conditions. When off normal by more than a few degrees, the echo returned from a smooth plane surface is very tiny indeed.

Tests were made on reflexions from

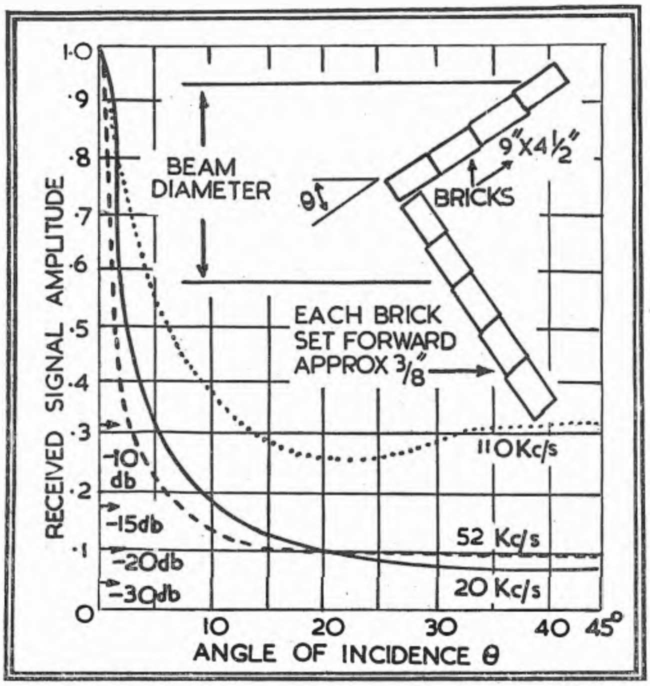


Fig. 5(a) Approximate course of scattered or reflected signal from a rough loose brick corner, as angle of incidence is changed

bricks arranged roughly like a wall, as shown in Fig. 5(a) and from a mortared brick wall. These results are illustrated in Figs. 5(a) and 5(b) respectively. In each case the beam was horizontal. The directivity of the receiver was small, but the half-amplitude beam widths of the transmitter were about 12½°, 12° and 3½° for frequencies of 20, 55 and 110 Kc/s., respectively.

Discussion of Results and Conclusions

Analysis of the received energy levels shows that the equipment is working very much more efficiently at 50 Kc/s. than at 110 Kc/s. Allowing for this, the scattering from small objects, such as screws and cinders on the cinder path, was very much greater with the higher frequency. When detecting an obstacle such as a lamp-post, returns appear to be most reliable when the beam is directed at its foot. The only example of a down-going step which was tried gave rise to a discrete reflexion which was quite marked at 10 ft. and, moreover, perhaps because the path preceding the step was slightly rough, a noticeable difference in the signal occurred when the beam was on the path compared with that when the beam proceeded unimpeded in air.

Owing to the high degree of directivity of the device, walls at oblique incidence gave very weak echoes. The scattering from walls, however, became quite marked at higher frequencies such as 110 Kc/s. (see Fig. 5).

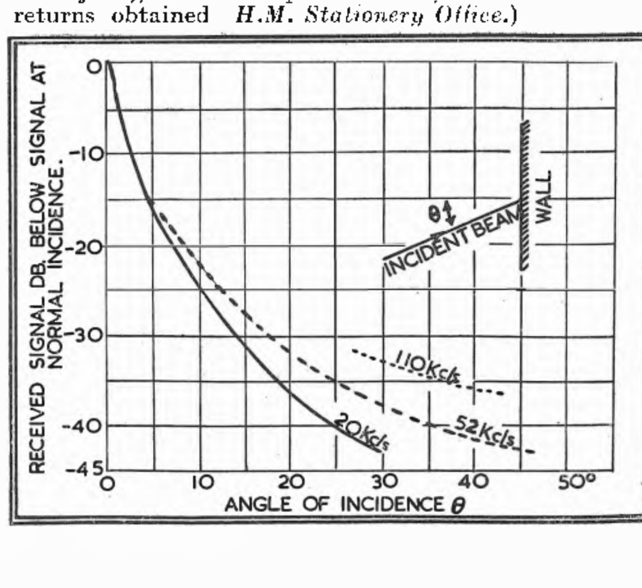
Useful returns were obtained from an automobile head-on at about 30 ft. Kerbs, if similar to a row of brick on the ground, give good reflexions provided that the beam is substantially normal to the edge. Similarly a wall gives excellent reflexions for normal incidence.

In general, there is a conflict between achieving high sensitivity of detection of small scattering objects by focusing the beam, (which is attended by good resolution of side-by-side objects), and the worsening of returns obtained from poor scattering surfaces, such as walls and the like which occurs through the enhanced directivity, since the latter inevitably accompanies the improved sensitivity when focused beams are used. For ranges of about 10 ft. it would appear advisable to use quite high frequencies of around 60 Kc/s. to make the best possible use of any roughness, and consequently scattering, which available surfaces offer. For ranges of about 30 ft., a frequency of around 20 Kc/s. seems suitable.

The high directivity of the beam which obtains when a reasonable compromise is struck between increasing equipment power and increasing sensitivity by focusing the beam is a serious drawback of the ultrasonic obstacle detector. This might possibly be overcome at the expense of some complexity in a Safety-in-Fog device by using two transmitting-receiving assemblies, one directed forward and the other sideways and down. Extensive trials would be needed to decide whether reliable indications were obtained from such equipment. For the Blind Man's Aid, however, the diverse nature of the hazards encountered would make most formidable demands on the equipment and it would be a very bold man who would prophesy even ultimate success for such a device in a portable form.

Acknowledgement is made to the Director of the National Physical Laboratory and the Chief Scientist, Ministry of Supply, for permission to publish this paper.

Fig. 5(b). Approximate course of scattered signal from mortared brick wall as angle of incidence is changed



A HIGH IMPEDANCE INPUT STAGE

for a Valve Amplifier

By P. O. BISHOP, M.B., B.S. (Sydney)*

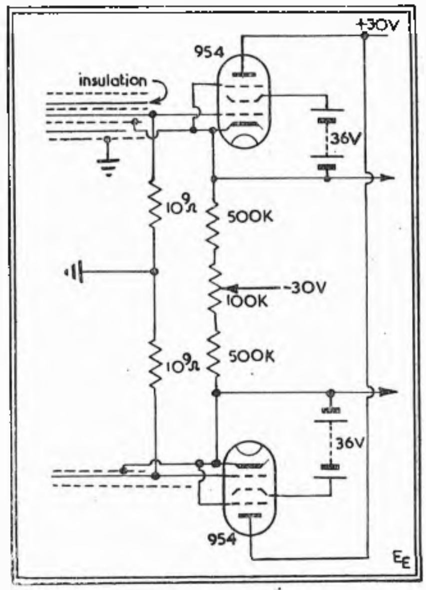


Fig. 1. Cathode follower input stage to a balanced D.C. amplifier

BY means of a valve amplifier it is possible to measure small changes in electrical potential having frequency components over a wide range even when they are derived from a source with a very high internal resistance. When the source impedance is very high and it is required to amplify and record a wide range of frequencies the use of a valve amplifier becomes essential. For this purpose a very high input impedance is required which normally calls for the use of special electrometer valves. Several attempts have been made to achieve the same result with common valve types. The methods adopted will be briefly reviewed and the application of these methods to the design of an input stage to a valve amplifier will be discussed.

The most important factors in determining the maximum resistance which may be placed in the grid circuit are the magnitude of the grid current and the nature of the grid current characteristics. By the use of common valve types under reduced operating potentials it is possible to achieve grid currents of 10^{-12} ampere or less. Nielsen[1] reviewed the earlier publications and investigated the possibilities of using the types 38, 954 and 959 as reduced grid current valves. He includes much quantitative information showing the dependence of grid current upon applied potentials and reports grid currents less than 10^{-15} ampere in the 959 valve associated with a stability comparable with that of special electrometer valves. Reducing the filament temperature and anode potential will minimise the grid current from all sources except that due to insulation or surface leakage and the portion that results from the emission of positive ions from the cathode.

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The grid current due to positive ion emission can be substantially reduced by using an "electrometer connected" pentode in which the suppressor electrode ($G3$) acts as the control grid and the screen acts as the space charge grid shielding the control grid from cathode ions. The normal control grid ($G1$) is operated at a small positive potential relative to the cathode. It is not possible to use an "electrometer connected" valve as a true cathode follower because variations of control grid ($G3$) potential have relatively little effect on the total cathode current. The control grid in this case exerts its effect by partitioning the cathode current between the screen grid ($G2$) and the anode. Grid currents as small as those reported by Nielsen cannot be expected when the grid ($G1$) is used as the control grid in a normal cathode follower circuit. With due precautions for minimising surface leakage the lower limit to the value of the grid current in a valve operated as a cathode follower will be set by the positive ion current from the cathode and will be of the order of 10^{-13} ampere.

Despite this limitation, the cathode follower has many advantages that make it desirable as the input stage to an amplifier. The effect of feedback in increasing the grid-cathode resistance and reducing the grid cathode capacitance is well known. A further important property of this circuit was reported by Sowerby[2] in that it allows a much higher resistance to be placed in the grid circuit without causing instability than would be the case if the valve were operated in a normal amplifying stage. The explanation of this observation has been given by Crawford[3]. The maximum value of grid leak with which stability can be maintained is given by the expression $1/gmK$, where K is the maximum slope of the grid current/anode current curve and gm the transconductance at that point. With a cathode follower the effective transconductance becomes

$$gm(eff) = gm \frac{1}{1 + gmRc}$$

where Rc is the cathode load resistor. Thus, the maximum value of the grid leak (Rg) becomes

$$Rg(max) = \frac{1}{\frac{gm + Rc}{K}}$$

The use of a high cathode load resistor makes the variations of calibration with source impedance very small even when grid leaks up to 10^{12} ohms are used. The magnitude of the grid current is, however, not affected by the fact that the valve is a cathode follower and it will have the same value as that obtained with a normal circuit operating at the same anode voltage and current.

The acorn types RCA 954 (pentode) and 955 (triode) are very suitable for the input stage. They are very small and their electrodes are connected to leads brought out through seals well separated on the envelope. The cathode follower circuit shown in Fig. 1 was designed as the input stage to a balanced direct coupled amplifier.

The operating potentials and characteristics for the 954 and 955 are given in the table below.

	954	955
Heater potential	4V	4V
V_a	30V	36V
Screen grid (g_2)	36V	—
V_g	—1.4V	—1.5V
I_a (+ I_{g_2} for 954)	50 μA	60 μA
μ	—	25
g_m	170×10^{-6} mhos	130×10^{-6} mhos
R_a	>5 MΩ	$2 \times 10^{5}\ \Omega$
I_g	5×10^{-13} amp	5×10^{-12} amp

The choice of operating potentials is largely determined by the output impedance that can be tolerated. Reducing the operating potentials reduces the grid current but it also decreases the transconductance of the valve and so increases the output impedance of the cathode follower. The increase in anode impedance of the valve also requires a higher value of the cathode load resistor than would otherwise be the case. Thus the operating potentials chosen for the valve will be largely determined by the requirements of the particular application of the cathode follower. The circuit parameters given above gave an output impedance for the stage of about 10 KΩ. This did not limit the frequency response of the following amplifier which was designed to have a uniform amplification up to 10 Kc/s.

It is desirable to make the cathode load resistor as large as possible in order to avoid non-linear distortion with large input signals and in order to make the amplification of the stage approximate to unity. In the case of the triode valve with small input signals it is sometimes convenient to earth the cathode load resistor, 25K being a suitable value to give a grid bias of -1.5 V when using the operating potentials given above. In the case of the pentode the high anode impedance makes a high value of cathode load resistor essential and this requires a negative high tension supply. When the cathode follower is used as the input stage to a high gain direct coupled amplifier it is desirable to use wire wound resistors. This places a practical limit to the value of the load resistor rather than the available negative high tension supply. The potentiometer in the cathode circuit of Fig. 1 enables the D.C. levels of the two cathodes to be balanced. The actual value of the grid current for a given valve type varies from valve to valve by a factor of about ten. In the case of the triode, 955, the grid current was about 5×10^{-12} amp. while for the pentode it was about 5×10^{-13} amp. When the pentode is used the anode potential should be a few volts negative to the screen potential. Raising the anode voltage above that of the screen causes an increase in grid current.

The input capacitance is considerably reduced by operating the valve as a cathode follower. The capacitance between the grid and earth can be reduced in the same ratio as the reduction of the grid-cathode capacitance by joining the shielding on the grid lead to the cathode[4]. This shielding must be insulated from earth and the whole again covered with an earthed screen. To obtain the minimum input capacitance the valves should be mounted on the pick-up electrodes themselves or in such a way that the input grids are joined directly to the source of the E.M.F. With the 955 the effective input capacitance to the valve will be little more than the grid-plate capacitance (1.4 $\mu\mu$F). When the pentode is used the effective input capacitance is very much less, the calculated value being about 0.05 $\mu\mu$F. This is achieved by using small floating batteries to provide the screen potentials, so that the grid-screen capacitance is also reduced by the negative feedback. In practice stray capacitances associated with the pick-up electrode system are likely to be of a much higher order than the actual input capacitances of the valve.

References

[1] Nielsen, *Rev. Sci. Instrum*, 18, 18, 1947.
[2] Sowerby, *J. Sci. Instrum.* 21, 42, 1944.
[3] Crawford, *Electronic Engineering*, 20, 227, 1948
[4] Attree, *Electronic Engineering*, 21, 100, 1949.

A "Zero-Beat" Indicator for Heterodyne Measuring Systems

By K. GOLDSMITH, M.Sc., A.M.I.E.E.*

CATHODE-RAY tubes are widely used as detectors of frequency balance in heterodyne measuring systems, but the information given by the tubes does not lend itself readily to remote measurement and automatic control purposes. Electronic frequency meters, which are suitable for this purpose, become very insensitive in the range near zero frequency. If, therefore, an electronic frequency meter is to be used in a heterodyne system, some device must be incorporated which permits accurate detection of the zero frequency.

In the conventional heterodyne system, the frequencies of two oscillators, $f1$ and $f2$, are fed into a mixer circuit, the output of which, $f1-f2$, is applied to a frequency measuring circuit. When $f1 = f2$, the mixer output is zero. The introduction of an amplifier between the mixer and the frequency measuring stages does not materially affect the operation of the frequency meter. If, however, the amplifier is provided with a slight amount of positive feedback, it will become oscillatory as soon as the input impedance is sufficiently high. The feedback circuit and the time constant of the amplifier can be so arranged that it will be oscillatory only at very low frequencies, *i.e.*,

* Research Department, Lever Bros. & Unilever, Ltd., Port Sunlight, Cheshire.

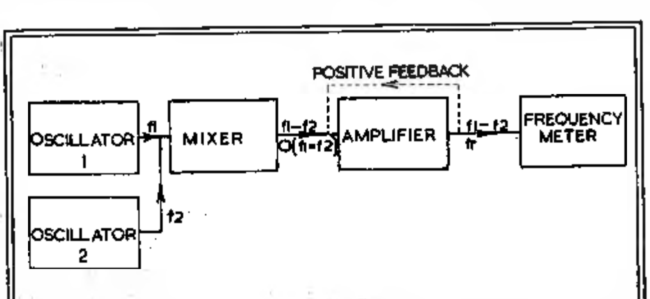


Fig. 1. Block schematic of the Zero-Beat indicator in a heterodyne circuit.

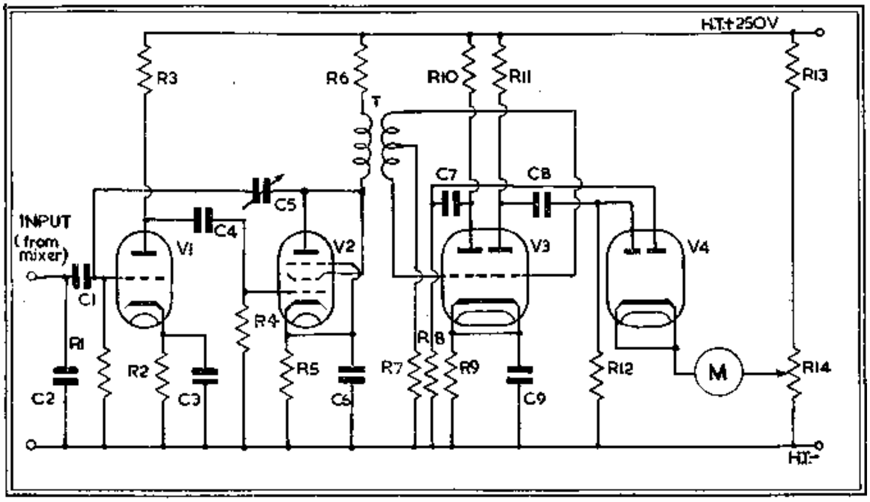


Fig. 2. Schematic of the amplifier and frequency meter

R1, R4, 1MΩ	R7, R8, R12, 27KΩ	C2, C7, C8, .0005μF	V2, KTZ 63
R2, 2.2KΩ	R9, 4.7KΩ	C3, C6, C9, 25μF	V3 ECC 35
R3, 270KΩ	R10, R11, R13, 100KΩ	C4, 0.01μF	V4, D 63
R5, 1KΩ	R14, 5KΩ	C5 Trimmer, 10-25pF	M, Milliammeter, 0-1m A
R6, 10KΩ	C1, 0.1μF	V1 H63	T, Intervalve Transformer

when the mixer output frequency approaches zero. The amplifier then functions like a super-regenerative circuit. At very low frequencies, its self-oscillation is modulated by the output frequency of the mixer, the oscillation building up to a maximum at zero frequency input. The oscillation of the amplifier will virtually cease when the mixer output frequency is increased, and the amplifier will then function normally. The frequency of self-oscillation of the amplifier (fr) can be made sufficiently high for the frequency meter to show a large deflexion at "zero-beat," where $f1 = f2$. A block diagram of this arrangement is shown in Fig. 1.

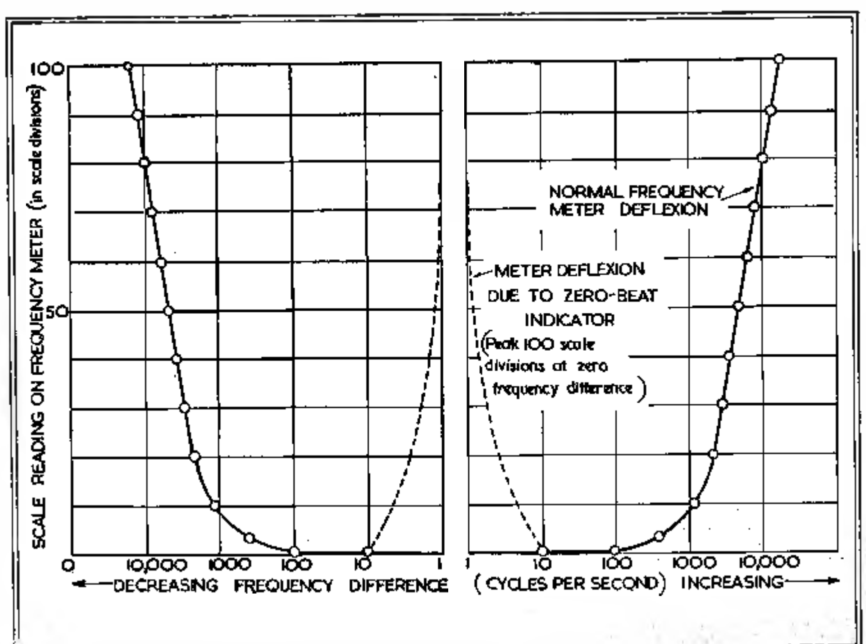
In the device here described, mixer and frequency meter are separated by a two-stage *R-C* coupled amplifier, the output of which is coupled to the input by means of a small trimmer capacitor.

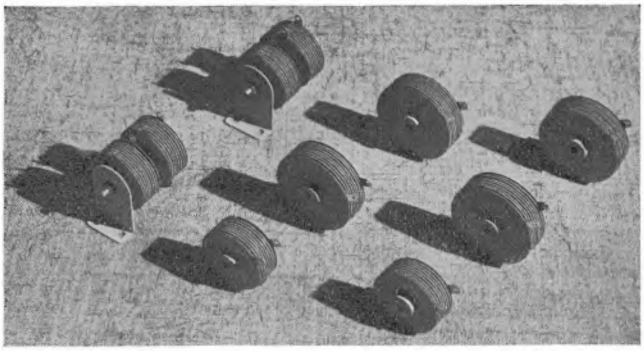
The amplifier frequency (fr) is chosen to give full-scale deflexion on the frequency meter at "zero-beat." The positive feedback, and hence the intensity of oscillation, can be adjusted by means of the trimmer. This should be adjusted to give very loose coupling, so that the oscillation can readily be stopped by small changes in the input frequency. Excessive coupling between amplifier output and input by stray capacitances should therefore be avoided. The frequency meter is of the *R-C* type, with an approximately linear response between 100 c/s. and 10 Kc/s. It can thus be used to measure the amount and detect the direction of the frequency deviation from zero. A circuit diagram of the amplifier and frequency meter is given in Fig. 2.

The advantage of using a "zero-beat" indicator in conjunction with an electronic frequency meter is illustrated in Fig. 3. The very flat response of the meter below 100 c/s. would render it useless as a detector in a heterodyne system, but, with the indicator, a sharp peak is obtained at zero frequency. The frequency band width at the base of the cusp of the "zero-beat" indicator is 20 c/s. in this case. This can be adjusted to some extent by means of the back-coupling of the amplifier. At very low frequencies, between 1 c/s. and 10 c/s., the modulation of the amplifier oscillation by the output frequency of the mixer results in pulses of the needle of the output meter *M*. Accurate zero balance can therefore be determined by observing the maximum steady deflexion of the needle, and small out-of-balance frequencies can be found by timing the pulses.

The "zero-beat" indicator has been used successfully in the measurement of dielectric constant by means of the heterodyne method. The indicator was found to be more convenient for visual indication of "zero-beat" over a long period of time than a cathode-ray tube. If an electronic relay is substituted for the output meter, remote indication of zero balance can be obtained, and this can be used for purposes of automatic control.

Fig. 3. Effect of the Zero-Beat indicator on the scale reading of a frequency meter in a heterodyne circuit





Electronic

A monthly record of British elec-
accessories, compiled from information

SenTerCel Miniature H.T. and H.F. Rectifiers

(Illustrated above)

To meet the need of the radio and electronic industry for miniature H.T. selenium rectifiers a new range of SenTerCel rectifiers has been developed.

The rectifiers are constructed to employ a tubular rivet instead of the conventional spindle, so reducing their size. Together with improved manufacturing technique, claim the makers, this enables the rectifiers to be produced at prices lower than the equivalent thermionic valve.

The range is made up of three basic types of half-wave rectifiers. If an output greater than can be obtained from a single rectifier is required, further rectifiers may be connected in series or parallel. An assembly of two rectifiers mounted on a bracket can be supplied.

The SenTerCel type M1 rectifier measures only $\frac{1}{8}$ by $\frac{1}{4}$ by $\frac{1}{4}$ in., and consists of a single element mounted in an aluminium case, weighing only 0.015 oz. With frequencies below about 5 Mc/s. it can usually replace a thermionic diode. In addition to the saving of space, the use of the M1 rectifier effects a considerable reduction in cost, for not only is the rectifier itself inexpensive, but the cost of a valve base and associated wiring is saved. As no heating is required, a low hum level in high impedance circuits is attained, and the heat loss of a thermionic valve is avoided.

Its average characteristics are:—

Self capacitance ...	20 pF.
Forward resistance at 5 volts D.C.	12,000 ohms.
Reverse resistance at 5 volts D.C.	20 megohms.
Maximum peak inverse voltage	50 volts.
Minimum A.C. input for satisfactory rectification	0.5 volts.

Standard Telephones and Cables Ltd.
Connaught House,
Aldwych,
London, W.C.2.

Ratings of SenTerCel H.T. Rectifiers

Type	RM.1		RM.2		RM.3	
Maximum ambient temperature	35°C.	55°C.	35°C.	55°C.	35°C.	55°C.
Maximum output current (mean)	60mA	30mA	100mA	60mA	120mA	90mA
Maximum input voltage (r.m.s.)	125 volts		125 volts		125 volts	
Maximum peak inverse voltage	350 volts		350 volts		350 volts	
Maximum instantaneous peak current ...	Unlimited		Unlimited		Unlimited	

A Low-Hum Input Pentode for Audio Amplifiers

(Illustrated below)

MULLARD Electronic Products, Ltd., have produced an input valve combining the features of high gain, low microphony and low hum: the EF37A pentode.

The valve is an improved model of the EF37, and should prove useful in the design of audio amplifiers operating from low input levels. Applications include microphone input stages, sound-on-film and disk-recording equipment.

The makers claim that the magnetic hum of the EF37A is less than one-fifth that of the EF37; the actual value, referred to the control grid, being less than 5 microvolts. The operating conditions of the new valve are identical with those of the EF37.

Mullard Electronic Products, Ltd.,
Century House,
Shaftesbury Avenue,
London, W.C.2.

Television Wobbulator

THE Type 36 Television Wobbulator has been designed for television manufacturers and those engaged on the development of television receivers. It is a mechanically swept complete visual alignment equipment enabling accurate response measurements to be taken. The display is viewed on a $3\frac{1}{2}$ in. cathode ray tube. The frequency modulation system sweeps 10 Mc/s.: 40-50 Mc/s or 8-18 Mc/s. outputs are switched from the front panel. A trace expansion system is incorporated enabling any 3 Mc/s. to be expanded to occupy the full 7 cms. "X" trace. The output is monitored and continuously variable from 1 μV to 100 mV; the output impedance of the attenuator being 75 ohms. The signal from the receiver under test is fed to a calibrated "Y" amplifier, which at maximum gain, requires an input of 1 volt to produce a 4 cms. "Y" trace. For production use master curves may be fixed into the tube mask and receivers aligned by unskilled personnel to these master curves. The size of the instrument is height $14\frac{1}{2}$ in. width $10\frac{1}{4}$ in., length 16 in.

The Type 39 Wobbulator is a similar instrument for use on Birmingham receivers. R.F. frequency 55-65 Mc/s. I.F. frequency 20-30 Mc/s.

Samwell and Hutton,
Combine Works,
Ilford, Essex

Equipment

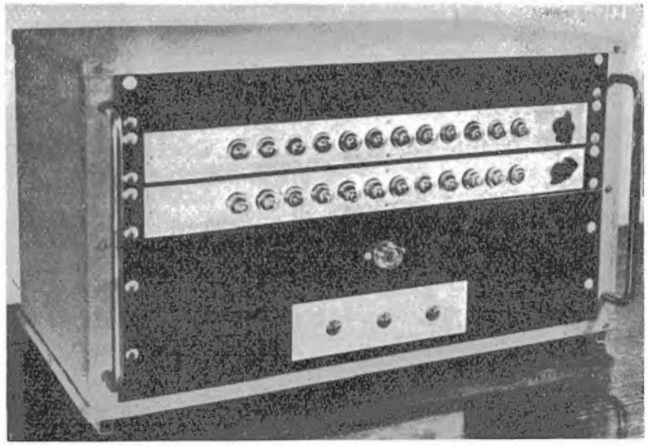
tronic apparatus, components and supplied by the manufacturers.

Dynamic Balancing Machine

THIS apparatus is designed to measure out of balance components on mechanisms weighing up to 7 lb. and gives direct readings, electrically indicated. The machine consists of a cradle upon which is mounted the test specimen, the cradle being supported so that it can vibrate freely in all planes. Electrical voltages are derived from the supports of the cradle and are amplified to a suitable level. The test piece is rotated at speeds from 1,000 to 3,000 r.p.m. by means of a belt driven from an electric motor mounted above the cradle. Any out of balance components will cause the supporting structure to vibrate, and generate a voltage proportional to the amplitude of the vibration. The high gain amplifier will measure vibrations as small as 0.000025 inches, and by means of a filter network only those vibrations that occur once each revolution are recorded.

By means of switches on the control unit the amount and angle of unbalance are indicated. A stroboscopic light source produces a pulse of light which is electrically timed to coincide with the unbalance of the rotating work piece. By means of a scale mounted on the workpiece only the appropriate section is shown up by the light source.

Dawe Instruments, Ltd. Hanwell, London, W.7.

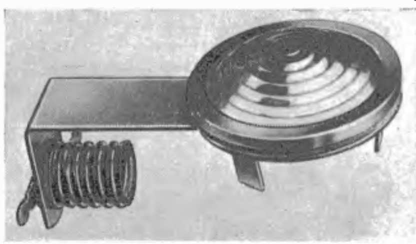


Indicator Lamp

(Shown below)

THE new Bulgin signal lamp bush and holder can be fitted to panels up to ½ in. thick, only a single fixing hole being required. The thermo-plastic lens can be supplied in a variety of colours, and, in quantity, bushes can be given any of the usual metal finishes to order. Normal stocked finish is polished nickel plating. The holder takes mains voltage 15 watt lamps, S.E.S. cap type (B.S.98/E.14).

A. F. Bulgin & Co. Ltd. By-Pass Road, Barking, Essex.



The Elliott Potentiometer Recorder

(Illustrated right)

THE Elliott Potentiometer Recorder is a continuous type high speed recorder, taking only three seconds to move across the chart. It has been simply designed, consisting of interchangeable sub-assemblies, which facilitate servicing, and combines a magnetic inverter and oil-immersed slide wire.

On the same panel is mounted the Elliott pneumatic control system, which is very flexible. The various control elements can be accommodated in the recorder casing as shown, or situated in the plant where convenient.

The system incorporates the Elliott "Pneulec" electro-pneumatic transformer which converts electrical signals into proportionate pneumatic signals, and the Elliott "Trimod" pneumatic controller to produce proportionate integral and rate functions. Features of the controller are: sealed system, calibrated setting and exceptionally long integral times.

Elliott Brothers (London) Ltd. Century Works S.E.13.

Electronic Counter—Batcher Type E.C.B. 144

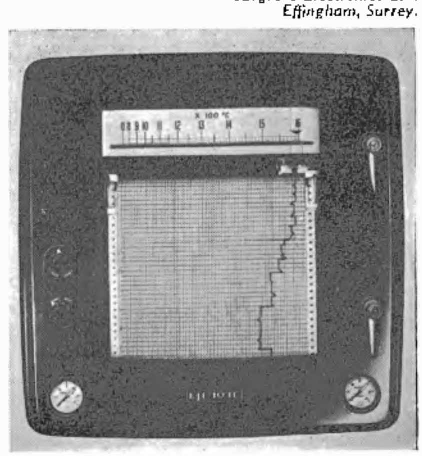
THIS instrument (illustrated above) has been developed to meet the demand for an apparatus at a reasonable price that will fill the needs of manufacturers and packers interested in the counting and batching of small articles at high speed. The maximum counting speed of which this apparatus is capable can be fully utilised only in certain scientific applications.

The E.C.B.144 will count and batch in quantities predetermined by the setting of two switches, and give visual indication of units, tens, dozens and grosses or any other combination in this range, and will automatically repeat the cycle on completion of each batch.

Batching can be effected by an electro-mechanically operated trap or gate specially designed for the articles to be batched, which diverts the stream of articles from the full container to the empty one waiting. At the same time a record of batches completed may be obtained on an electro-magnetic counter which, if required, can be positioned remote from the main apparatus.

The largest batch for which the standard model counter can be used is one gross, but the addition of one further stage will enable the instrument to operate up to 12 gross.

Sargrove Electronics Ltd. Effingham, Surrey.



BOOK

Terrestrial Radio Waves

By Dr. H. Bremmer. 1st Edition. 343 pp. 91 figs. Elsevier Publishing Co., distributed by the Cleaver-Hume Press. Price 42s.

PHYSICISTS and engineers concerned with the theory of the propagation of radio waves round the earth often find themselves interested in the relations between the radio theory and the theory of allied phenomena in other branches of physics. For example, when considering diffraction round the earth they are reminded of problems concerning the interaction of a parallel beam of radiation with a conducting or dielectric sphere, and the application of the results to scattering from small particles, either in colloidal solutions or in the rainbow. The "skip distance" phenomenon encountered when waves are propagated through the ionosphere presents interesting analogies to the optical phenomena near a caustic; when the magnetic field of the earth is taken into account the ionisphere becomes doubly refracting so that it is possibly to use the theoretical methods applicable to the propagation of light in crystals, and the deduction of the wave- and ray-velocities is of importance. The propagation through an inhomogenous medium has many analogies to the problems encountered in wave-mechanics.

In this book, "Terrestrial Radio Waves," Dr. H. Bremmer attempts to survey and correlate the highly mathematical work of Watson, Love, Eckersley and Millington, van der Pol and Bremmer, Wedensky, Booker and others, also to show how the radio problem is related to those other physical problems mentioned above. It seems to the reviewer that those who worked on these theories of radio-wave propagation were primarily mathematicians, interested more in the mathematical methods than in physical explanations, and it was hoped that the author of the present book would have been able to explain the essentials of the problems by some simple physical arguments. He has not, however, found this possible. Instead he outlines the various types of mathematical approach, shows how they are related, and then points out what the mathematical results mean physically. This is interesting, and valuable, but does not help the physicist very much: he is left in the position of having to accept the very complicated mathematics, though he is given some help in their interpretation.

To those interested in the different types of theory the book should be a useful guide, though it will be necessary for the reader to consult the original papers before he can follow the arguments in detail. For others who are interested in results the numerous graphs which summarise the theoretical deductions in several important special cases will be useful. Those who think, as the reviewer does, that there is usually a simple explanation of natural phenomena, will be disappointed that such complicated mathematics is still necessary in order to explain the behaviour of the waves, and will feel that there is still room for someone to simplify the presentation of the theories. They will, however, be grateful to the author for giving them some idea of how nature works by drawing attention to the similarities between diverse physical phenomena.

In at least two important fields the book contains material hitherto unpublished. In one of these the reflexion of very long waves from a sharply-bounded ionosphere in the presence of a magnetic field is computed: in the other the focusing and absorbing effects of the ionosphere on radio waves incident from outside the earth is discussed. Other topics include diffraction round the earth and propagation through an inhomogeneous medium, treated by ray and wave methods, and with applications both to tropospheric and ionospheric propagation.

J. A. RATCLIFFE.

Waveforms

By Britton Chance, V. Hughes, etc. M.I.T. Radiation Laboratory Series; volume 19. 785 pages. McGraw Hill. 85s.

IN a book of this magnitude (nearly 800 pages) it is difficult in a short review to do full justice to its contents. It is essentially a reference book to be consulted on occasion rather than to be read minutely from cover to cover. The title, which has the merits and demerits of brevity, hardly gives an idea of the contents, which deal with the generation of almost every (at present) useful wave form from sinusoidal to pulse, and their amplitude and time selection, comparison and discrimination. Sections are also included on amplitude and time modulation and demodulation, on methods of multiplying and dividing frequency, and on the use and control of electrical waveforms in performing the equivalent of simple (counting) and complicated (differentiation, square root, etc.) mathematical operations. Full acknowledgement is made to the considerable contributions made in this field by British workers and in particular to F. C. Williams.

There are 23 chapters, two appendices

REVIEWS

(on the negative capacitance and the cathode compensated amplifier), a two-page glossary and an appendix. Chapter 1 affords an excellent introduction, indicating the relationship to preceding and succeeding volumes in the M.I.T. series. Volume 17 on components is stated to be an essential companion to this volume if the precision circuits described are to be constructed. In the latter part of this chapter (further amplified in Chapter 2) F. C. Williams discusses pulse shaping by linear networks (*R*, *L* and *C*) and by non-linear devices such as valves, using the cause and effect diagrams originally presented in his paper* to the I.E.E. Radiolocation Convention. Chapter 3 considers the use of non-linear circuits in performing the basic operations of amplitude and time selection, discrimination and comparison of waveforms.

A succinct and comprehensive account of sinusoidal waveform generators is provided in Chapter 4; the subject matter, ranging from crystal controlled radio frequency oscillators to phase shift and bridge controlled audio frequency oscillators, is of interest to radio engineers generally. Short duration waveforms (generally less than 0.1 microseconds) having abrupt changes of shape are dealt with in the next two chapters, the first of which treats multivibrators and phantastron type circuits. This and the next chapter on blocking oscillator and delay-line pulse generators really cover some of the ground surveyed in Volume 5, but the method of presentation here will have greater appeal to the general circuit designer and student. In chapter 7 is a description of the generation and uses of triangular waveforms, and the next is devoted to special types of waveforms made up of a mixture of linear and curved shapes, which in their variety and possibilities will stagger the "plain" electrical engineer.

Amplitude selection, comparison and discriminate circuits are reviewed in the ninth chapter. The importance of the diode (often in association with a cathode follower) as a selector is emphasised, and it is shown that comparison is achieved by using the input wave (or a modified form of it) to trigger some regenerative device, and that discrimination involves the difference between two voltages as the operational feature. Time selection requires a "gating" pulse and chapter 10 deals with circuit arrangements.

The difficulties associated with the amplification of waveforms containing D.C. components can be lessened by using the wave to modulate a carrier which is then amplified and later demodulated. A useful summary of methods of modulation and a table of performance of recommended circuits are found in Chapter 11. The title of Chapter 12 "Electromechanical Modulators" is liable to shock many readers, (if they have forgotten the carbon microphone), since it deals with transducing systems for changing a mechanical displacement into a directly related electrical amplitude variation. The performance of four devices, potential divider, variable coupling transformer, variable capacitor and photoelectric system, are considered and their performances summarised in a table. The importance of time modulation (Chapter 13) needs no stressing for radar work, and its usefulness is being exploited more and more for measurement and computing.

The basic principles of amplitude and time demodulation of non-sinusoidal waveforms are shown in Chapter 14 to be the same as for sinusoidally varying signals. Thus amplitude modulation requires a peak detector and for time demodulation an area detector (often known as a counter) is necessary, or the time variation must be converted first into an amplitude modulation.

The next three chapters on sinusoidal and pulse recurrence frequency division will be of particular interest to designers of television synchronising pulse generators. Electrical circuits for performing mathematical operations are examined in Chapters 18 and 19. A description of oscilloscope techniques follows and contains nothing new to users of this instrument.

The storage of information on a special photo-sensitive surface in a cathode-ray tube is a comparatively new development and Chapter 21 makes no pretensions to completeness. The characteristics of electrical delay lines (for delays up to about 10 microseconds) and of supersonic delay lines (giving delays up to several milliseconds) are discussed in the last two chapters.

For the circuit designer this is one of the most useful books in the whole of the M.I.T. Radiation Laboratory Series, and is one that the teacher of advanced circuit technique and the television specialist will certainly want to possess and use.

K. R. STURLEY

* Introduction to Circuit Techniques for Radiolocation. *Journal I.E.E.* Part IIIA, March, 1946.

Electronics in the Factory

Edited by Prof. H. F. Trewman. 183 pp. 63 figs. Pitman & Sons, Ltd. 20s. net.

THIS book has been compiled by members of the staff of Electrical and Musical Industries, Ltd.—in fact the company's monogram appears on the cover. Nevertheless, it must not

BOOK REVIEWS *(continued)*

be considered as a one-sided book; the contents are well representative of all branches and manufacturers, and the fact that E.M.I. have put their imprint on it is perhaps a guarantee of the quality of the contents.

One may say that at the start that survey is very well carried out. The writing is clear and not too tedious to to be read by the directors, general managers, and production engineers to whom the book is addressed. The chapters are headed: Time Delay and Timing Circuits; Counting Equipment; Motor Control; Voltage and Current Regulation; Electronic Heating; Welding Control; Servo Mechanisms; Photocell Applications; and there are concluding chapters on electronics in medicine and chemistry, not forgetting strain gauges, moisture indicators and ultrasonics.

The introductory chapter gives an excellent picture of the relations between the electronic engineer and the factory engineer, and points out the necessity of the works electrician having some knowledge of electronic devices in order to save time and expense in calling in the expert for comparatively trivial faults. In the main text, no attempt is made to make the examples exhaustive—such a task would belong to an encyclopaedia of electronic applications—but the descriptions of typical installations are sufficiently thorough to suggest other applications to specific problems. And, of course, there is an experienced consultation service available to those who have such problems (*vide* p. 189).

A good book, which should enhance the reputation of E.M.I. Institutes and its able Professor.

G. Parr

Discharge Lamps for Photography and Projection

by H. K. Bourne, M.Sc., M.I.E.E., F.R.P.S. Chapman & Hall, 36s.

THE steadily growing application of discharge lamps to photography, projection and lighting in general has created a demand for a book which describes the lamps and gives performance data for various conditions of operation. Mr. Bourne's book not only fulfils this demand and discusses a number of specific applications but also gives a clear account of discharge lamp development and design, so that the reader can assess the suitability of these sources for various purposes.

The subject matter is systematically presented and the numbering of the paragraphs on the decimal system makes for easy reference. Chapters 1 to 4 give the lighting requirements for photography and projection and the behaviour of tungsten filament lamps and carbon arcs for these purposes.

Chapters 5 to 11 are devoted to mercury vapour discharge lamps. It is always difficult to decide how much of the theoretical and fundamental background should be discussed, but Mr. Bourne includes just sufficient of the physics of the discharge to explain the important characteristics in simple terms. For those who wish to delve deeper into the theory there is an excellent bibliography at the end of each chapter.

There are one or two minor criticisms of the theoretical matter: in paragraph 5.3 page 67, a little more explanation is needed to correct the impression that luminous efficency is directly related to the values of excitation potentials at which visible light is emitted.

In paragraph 10.3 page 196 the size of the anode relative to the cathode in a D.C. lamp is attributed to a higher voltage drop at the anode: surely the explanation lies in the fact that the current is carried mainly by electrons which must dissipate energy when they arrive at the anode. However, these are small details in an otherwise excellent account.

Mr. Bourne's long experience in the field of high pressure mercury vapour lamps has enabled him to treat this section of the book with particular thoroughness. This is fortunate, as so little of this work has been published in book form in the English language. Moreover, the small size, high intensity sources which the mercury arc can provide are of special interest for photography.

In Chapter 12 flash discharge lamps are described and compared with photo flash bulbs. Repeated flash or stroboscopic lamps are also discussed with reference to a number of commercially available equipments.

Among the applications of discharge lamps in Chapter 13 perhaps the most important is film studio lighting. The compact source lamp is already in use in the studios in considerable numbers. The lamps and equipment are basically as described, and changes since this book was prepared are mainly towards simplification of the equipment and the development of larger units.

In addition to clear diagrams and illustrations on almost every page, the book contains useful appendices including definitions of terms used in photography and illumination and a collection of photographic and optical data.

In short, Mr. Bourne's book is thoroughly recommended not only to the photographic or projection expert but also to lighting engineers in general.

G. G. Isaacs

NOTES FROM THE I DUSTRY

Television Servicing Certificate Examination

The Radio Trades Examination Board and the City and Guilds of London Institute announce that the first Television Servicing Certificate Examination will be held on May 2 and 4, 1950, and the practical examination on a date to be announced later. In this instance London will be the only centre and it may, therefore, be necessary to restrict the number of entries. Admission to the examination is limited to candidates who have passed one of the following examinations:—

(i) The Radio Servicing Certificate Examination held jointly by the City and Guilds of London Institute and the Radio Trades Examination Board,

(ii) the examination in Radio Servicing held by the Radio Trades Examination Board from 1944 to 1946,

(iii) the examination in Radio Service Work of the City and Guilds of London Institute held from 1938 to 1947,

(iv) the "third year" examination in Radio Service Work of the Union of Lancashire and Cheshire Institutes,

(v) the examination in Radio Servicing held prior to 1944 by the British Institution of Radio Engineers,

(vi) the examination in Radio Servicing held prior to 1944 by the Scottish Radio Retailers' Association.

The closing date for the examination is Thursday, 15 December, 1949. Regulations and entry forms are obtainable on application to the Secretary of the Board, 9 Bedford Square, London, W.C.1.

Large Screen Home Television

Philip's Electrical, Ltd., recently demonstrated an adaptation of their projection unit for domestic television receivers (described in ELECTRONIC ENGINEERING, 21, 259, 1949) to give a four by three feet image on a home-ciné type of screen. The only modifications required to give this size of picture is a change of Schmidt corrector lens and an increase of projectory distance to nine feet.

Tube life is estimated to be normal (i.e., 1,000 hours) and replacements will not cost more than 50 per cent of direct-viewing tube prices. The complete projection receiver will probably retail at a similar price to present 12-in. tube console models.

The Science Museum Televisor

The Science Museum have honoured us by accepting a working model of the Home Built Televisor for exhibition in the Electronics Section. The model specially built for this purpose by the designers, has now been installed, and may be seen during the normal Museum hours in the Radio and Television Section of the gallery above the main entrance.

Educational Films

The British Electrical Development Association has produced four more educational films explaining in the simplest terms, and with commendably clear demonstrations, the theory of electrical phenomena.

"What is Electricity" describes in two parts the electronic composition of conductors, and how this facilitates the flow of current.

"Electricity and Movement" shows how electricity was harnessed to supply one of man's most essential needs, rotary motion.

"Putting Free Electrons to Work" continues the theory of electron movement to explain the action of simple valves.

"Alternating Current and Direct Current" outlines the difference between the two types of electric mains supplies and why D.C. has lost favour compared with A.C.

Twelve of these instructional films have now been completed. Each lasts about ten minutes and is available on both 16 mm. and 35 mm. film on free loan to responsible organisations. Application should be made to the Secretary, British Electrical Development Association, 2 Savoy Hill, London, W.C.2.

B.B.C. Engineering Staff Changes

The B.B.C. announce that it has decided to split the Operations and Maintenance Department of the Engineering Division into two parts. One part, consisting of the Studio, Transmitter, Recording and Lines Department, will continue to be in the charge of Mr. L. Hotine, Senior Superintendent Engineer.

Mr. M. J. D. Pulling, M.A., M.I.E.E., has been appointed to take charge of the other part, the Television Department, with the title of Senior Superintendent Engineer, Television.

Mr. D. C. Birkinshaw's post as Superintendent Engineer, Television, is not affected.

Timula Cement

Timula Cement is being used by a number of wireless set repairers for refixing loose top-cap terminals and loose bases of radio valves with satisfactory results.

Timula adheres strongly to metal, glass and wood, and self-sets in a short time to a porcelain-like hardness. It withstands high and intermittent heat, without contracting, cracking or crumbling.

Brochure on Apprenticeship

The English Electric Company has, for many years, paid particular attention to evolving a good scheme for the training of apprentices and students in all branches of engineering. Among the 35,000 workers employed by the "English Electric" group of companies, there are some thousands of apprentices of all types, and the management have thought that, in view of the present need which exists to reinforce the ranks of trained technical personnel, it would be appropriate to summarise their activities in this direction in a brochure.

To preserve the high standard of technical skill necessary to maintain and enhance Britain's engineering prestige, it is felt desirable to do everything possible to draw attention to some of the facilities offered to young men to take up engineering training, and this booklet gives them a glance of what is happening in the English Electric group.

Salvaging Electrically Twinned Quartz

In the above article the following corrections should be made:

P. 413. In Fig. 5(c) the diagrams for before treatment and after treatment should be interchanged.

P. 414. In Fig. 8 the remainder of the caption after 22 Kg-cm should be omitted.

DEC MBER MEETINGS

Institution of Electrical Engineers

Unless otherwise stated, all meetings are held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Radio Section

Date: December 7. Time: 5.30 p.m.
Lecture: "Solar Radio-Frequency Radiation."
By: J. L. Pawsey, M.Sc., Ph.D. (Read by J. S. Hey, M.B.E., M.Sc.)
Date: December 19. Time: 5.30 p.m.
Informal Lecture: "The Acoustics of Studios and Auditoria."
By: W. Allen.

Secretary, Institution of Electrical Engineers, Savoy Place, W.C.2.

Cambridge Radio Group

Date: December 13. Time: 6 p.m.
Held at: Cambridgeshire Technical College.
Address by: R. T. B. Wynn, C.B.E., M.A., Chairman of the Radio Section.

Secretary: G. E. Middleton, M.A., University Engineering Laboratory, Cambridge.

South Midland Centre

Date: December 5. Time: 6 p.m.
Held at: The Town Hall, Birmingham.
Lecture: Faraday Lecture on "Radar."
By: R. A. Smith, M.A., Ph.D.

Date: December 20. Time: 6 p.m.
Held at: James Watt Memorial Institute, Great Charles Street, Birmingham.
Lecture: "Electricity in the Service of Man."
By: P. Dunsheath, C.B.E., M.A., D.Sc.

Secretary: H. Hooper, British Electricity Authority, 53 Wake Green Road, Moseley, Birmingham 13.

North Staffordshire Sub-Section

Date: December 9. Time: 7 p.m.
Held at: King Edward Grammar School, Stafford.
Discussion on: "Rectifiers."
Opened by: J. E. Boul.

Secretary: D. Smith, B.Sc.(Eng.), 82 Beatty Hall, Stone, Staffs.

The Royal Society

Date: December 15.
Lecture: The Wilkins Lecture for 1949.
By: Professor E. N. da C. Andrade, F.R.S.

The Secretary, The Royal Society, Burlington House, London, W.1.

Inc. Radio Society of Great Britain

Date: December 16. Time: 6.30 p.m.
Held at: Institution of Electrical Engineers, Savoy Place, W.C.2.
Annual General Meeting.

General Secretary, New Ruskin House, Little Russell Street, W.C.1.

Institute of Physics

Manchester and District Branch

Date: December 9. Time: 7 p.m.
Held at: The New Physics Theatre, University of Manchester.
Lecture by: Professor P. M. S. Blackett, F.R.S.

Secretary: Dr. F. A. Vick, O.B.E., F.Inst.P., Physics Department, The University, Manchester 13.

Electronics Group

Date: December 13. Time: 5.30 p.m.
Held at: The Institute's House, 47 Belgrave Square, S.W.1.
Lecture: "The Nervous System as an Electrical Machine."
By: Dr. W. Grey Walter.

Secretary: G. W. Warren, F.Inst.P., Research Laboratories, The G.E.C., Ltd., Wembley, Middx.

Institute of Navigation

Date: December 16. Time: 5 p.m.
Lecture: "Radar Charts."
By: Lt. Commander P. G. Satow, D.S.C., R.N.

Executive Secretary: M. W. Richey, The Institute of Navigation, c/o. Royal Geographical Society, 1 Kensington Gore, London, S.W.7.

British Institution of Radio Engineers

London Section

Date: December 15. Time: 6.30 p.m.
Held at: London School of Hygiene and Tropical Medicine, Gower Street, W.C.1.
Lecture: "Electronics in Aircraft Design."
By: A. L. Whitwell.

The General Secretary, 9 Bedford Square, London, W.C.1.

North-Eastern Section

Date: December 21. Time: 6 p.m.
Held at: Neville Hall, Newcastle-upon-Tyne.
Lecture: "A Review of the Basis of Electronics."

Secretary: c/o. 26 Denewell Avenue, High Heaton, Newcastle-upon-Tyne.

South Midlands Section

Date: December 15. Time: 7 p.m.
Held at: The Technical College, the Butts, Coventry.
Lecture: "H.T. Supply for High Power Transmitters."
By: Mr. Lane.

Secretary: C. Stokes, B.Sc., 6 Esterton Close, Coventry.

Scottish Section

Date: December 1. Time: 6.30 p.m.
Held at: Electrical Department, The University, Glasgow.
Lecture: "Electronics in Industry."
By: A. A. M. Turnbull.

Secretary: A. A. M. Turnbull, 68 Launderdale Gardens, Glasgow W.2.

Television Society

Constructors' Group

Date: December 8. Time: 7 p.m.
Held at: Cinema Exhibitor's Association, 164 Shaftesbury Avenue, W.C.2.
Lecture: "Baird Television Receivers."
By: P. Wigley, B.Sc. (Scophony-Baird, Ltd.)

Main Society

Date: December 30.
Held at: Cinema Exhibitor's Association, 164 Shaftesbury Avenue, W.C.2.
Exhibition and Social.

Secretary: T. M. Lance, 35 Albemarle Road, Beckenham, Kent.

Bedford Centre

Date: December 14. Time: 7.30 p.m.
Held at: Flying Services Club, St. Mary's Street, Bedford.
Lecture: "Television Aerial Problems."
By: E. M. Lee.
Date: December 30. Time: 7.30 p.m.
Held at: Flying Services Club, St. Mary's Street, Bedford.

Discussion Group

Secretary: M. Bradbury, 36 Grafton Road, Bedford.

Midland Centre

Date: December 5. Time: 7 p.m.
Held at: Lecture Hall (1st Floor), The Crown Restaurant, Corporation Street, Birmingham.
Open Meeting.

Secretary: W. Summer, 31 Beech Road, Bournville, Birmingham 30.

Bristol and South Western Centre

Date: December 6.
Held at: The Royal Hotel, Bristol.
Lecture: "Television Aerials and Interference Problems."
By: E. M. Lee.

Secretary: A. G. Williams, 43 Horse Street, Chipping Sodbury, Bristol

Radar Association

Date: December 6. Time: 7 p.m.
Held at: Albert Tavern, Victoria Street, London, S.W.1.

Monthly Meeting

Hon. Secretary, Technical Committee: J. C. Warren, 57 Gallows Hill, Kings Langley, Herts.

The Institution of Post Office Engineers

Date: December 6. Time: 5 p.m.
Held at: Institution of Electrical Engineers, Savoy Place, W.C.2.
Lecture: "Some Recent Developments in Telegraph Apparatus."
By: R. O. Carter, M.Sc., D.I.C., A.C.G.I., A.M.I.E.E., and L. K. Wheeler, B.Sc., A.M.I.E.E.

Secretary: W. H. Fox, A.M.I.E.E., Engineer-in-Chief's Office, (T.P. Branch), Alder House, London, E.C.1.