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*Invention in Relation to National Welfare and Legislative Control**

BY SIR AMBROSE FLEMING, M.A., D.SC., F.R.S. (President)

In complying with the request of our Council to give a Presidential Address to the Members of the Television Society, it seemed to me it would be better to confine my remarks to some topics of broad general interest to the Members rather than offer information on any special technical subject on which perhaps some present might be better informed than myself.

SIR AMBROSE FLEMING—PRESIDENT
[Courtesy "*Television*"

Television is one of the latest and most remarkable of the applications of scientific knowledge in the field of human inter-communication, and its great interest has therefore drawn very many to the practical study of its mysteries.

It occupies a similar place with regard to the eye to that filled by radiotelephony and broadcasting with regard to the ear. It enables us to see moving objects at a distant place concealed from us and in short to be in two places at the same time.

The questions then arise, how far do these remarkable technical applications of scientific knowledge truly contribute to national welfare in general and how far is it desirable they should be under any legislative or national control?

You are aware that the question has been very seriously discussed lately whether the world has not gone on too fast in mechanical invention, and in so-called labour-saving devices, speed of transport; substitution of mechanism for human labour and skill, creating therefore over-production and unemployment.

It is now seen that all these so-called improvements have a double aspect. They are advantages in some ways but often involve some grave disadvantages in others. They benefit some part of the community at the expense of others. They are capable of good and useful applications but also often provide intensive means for evil purposes and crime.

It cannot be said, for instance, that the invention of the petrol motor has been an unmixed blessing. It has enabled us to transfer goods and persons along high roads with five to ten times the speed of horse conveyance; but, it kills about seven thousand persons every year in Great Britain by motor accidents on those roads and injures many hundred thousands more. It has provided means of escape for criminals in smash and grab raids on banks and jewellers' shops. It gave us all the terrors of air attacks in the last great war, and would furnish appliances for annihilating the whole civil population of countries in the next one. The utmost that can be said for it is that is has enabled large numbers of persons to visit beauty spots or take journeys they would never otherwise have been able to do. The manufacture of motors and motor vehicles has created a new industry employing large numbers of persons but, it has created unemployment for those previously occupied with the breeding, and use of the horse. It has unquestionably seriously injured the earning power of our railways.

With regard to wireless broadcasting, which all centres round the invention and improvements in the thermionic valve both for transmission as well as reception, there are no such disasters to life or evil applications as in relation to the petrol motor,

* An address given to the Television Society on March 14th, 1934.

but nevertheless there is the same double aspect of benefits and injuries.

Before the advent of universal music broadcasting the only way in which people could hear good music was by attending concerts. Nearly evey town had its musical society, and more than one in large cities and the demand for musical ability created the supply. But now that music is supplied as it were, " on draught " by the B.B.C. and other foreign equivalents and everyone who can buy a good receiver can listen-in to the finest music, it has without doubt injured the musical profession. It has brought musical talent more into bondage to single controlling organisations and diminished the opportunities for profitable independent employment. On the other hand it has created a great radio manufacturing industry for the supply of receiving sets, and in all the work connected with the provision of the music-modulated electric waves sent out from the radio stations.

As regards the picture palace industry with its use of talking films; I have not the data to offer any opinion how far it has injured the theatrical profession and the demand for the legitimate drama, but it must have had some effect upon it.

With respect to Television it is perhaps too soon to pronounce any opinion how far it may interfere with other industries or create a new one. It has not yet had a fair chance to prove its entertainment value. I will refer presently to the effects of legislative control, but meanwhile it may be said that many think it is being held back by the over-cautious or unenterprising spirit of the B.B.C. with regard to it.

Television has had little opportunity to show how far it appeals to the general public, when the only regular exhibition of it given by the B.B.C. so far is at 11 p.m., when all children and many adults are fast asleep. No show can have any fair innings when given at that ridiculously inappropriate hour. Hence if invention in connection with it is to have a reasonable chance the first thing to do is to besiege the present controlling authorities to give an opportunity to it at an hour of the day when it will be possible for those likely to buy television receivers to avail themselves of them. The argument that has been used against it is that the entertainment value is at present small.

Musical or speech broadcasting has an unlimited quantity of material to broadcast, but it is said that the limited range of the living objects which can be included in the television screen sets a limit also to its amusement utility. But, I have long been of opinion that this objection would be to a very great extent removed by the Television of suitable films taken with the moving picture camera. I say *Suitable* films because it would not be the kind of subject filmed for the cinema but special subjects of large detail. Each separate picture on the film can be scanned in the time it is stationary for say 1/16th of a second and transmitted by wire or wireless. The possibility of this has been greatly improved by the progress made in short wave technique. We now understand that all radio transmission requires for proper isolation a certain width of wave length on either side of the selected carrier wave length and that within a certain octave of wave lengths, more wave bands can be allocated the smaller the wave length. Also with short wave lengths we can give more detail in the televised picture.

I regard this short wave film television as perhaps the most promising field for future broadcast and the most likely subjects to interest children and the public generally are the motions, actions and behaviour of animals and their trained performances.

There are yet difficulties to be overcome in the way of transmission, and reception of ultra short waves, but it is very remarkable that these waves seem to have power of passing through buildings and curving round the earth to a much greater extent than was anticipated. The trouble with atmospherics and fading, so marked in the case of medium wave lengths, is almost non-existent with them. The difficulties with construction of receivers for popular use are being overcome.

We may ask then the question, what is the special field for television which shall make it attract towards it continually inventive ability to improve and advance it? In the case of wireless telegraphy in its earliest days it was the remarkable and enormously valuable power it gave of communication from ship to shore or ship to ship, in all weathers and at all times. It vastly increased safety of travel by sea and saved a countless number of human lives in marine disasters, as in the case of the tragedy of the S.S. Titanic on her maiden voyage in 1912. Not a soul would then have survived to tell the tale but for the wireless.

A second attribute which gives it value is the power by which a single voice can reach the whole nation. Many present will remember that in the general strike of 1926 when newspaper circulation had been stopped, Mr. Stanley Baldwin was able by wireless to give a re-assuring verbal message to the nation to prevent alarm or misunderstanding.

The wireless speeches of our gracious King on the two last Christmas days established a direct and personal link between the Throne and the People which had vast utility and benefit.

The systematic broadcasting of speech and music is of immeasurable value to those living alone or in lonely places in dispersing discontent and solitude and it perhaps to some extent may be a means of preventing the constant tendency of population to desert the country and concentrate in the towns. Lastly we have the creation of a new and profitable industry employing thousands of persons in the manufacture and sale of wireless apparatus and design and erection of wireless stations.

Apart altogether from the general entertainment value of wireless broadcasting and the provision of a new amusement, we have the above solid gains to national welfare which must be set off against any possible disadvantages in the changes in demand for certain kinds of service or talent. It has undoubtedly inflicted certain disadvantages on the musical profession as already noted.

As regards the future of Television, I think one great field for useful work is in popular education, in other words, of lectures illustrated by television of pictures, such lectures being given by very competent teachers. Every teacher and educator knows perfectly well that to give an effective lecture you must appeal to the eye as well as the ear. You cannot do it by oral teaching alone. Hence, nearly every college lecture is illustrated by lantern slides. A lecture well illustrated by experiments, as are the Christmas Lectures at the Royal Institution, always draws large crowds. Every advertiser or tradesman knows that the mind is more easily reached through the eye than the ear.

At the present time the B.B.C. occasionally broadcast lectures to schools on music. But we can now perfectly well televise pictures, diagrams and drawings. We could for instance give a lecture on botany, architecture, physiology, or astronomy, in which the lecturer's spoken words, conveyed as usual by radio and repeated on loud speakers, at various schools, are also at the same time illustrated by television pictures.

When we can reproduce well, diagrams, pictures or photographs on a screen, three or four feet square, we can teach a class of 50 children at once and not only in one school but in a dozen at the same time. We can then avail ourselves of the highest teaching ability and enlist as teachers men and women of most special knowledge and great abilities. There must be a very limited demand to see by television two men boxing or a woman dancing at 11 p.m., but in the application of television in the field of education in school hours, there would be a practically unlimited scope for useful work. A school could afford to instal and work a more expensive or complicated television receiver than would be saleable for private use and in the same way at the transmitting end.

Against this, it might perhaps be said that any extensive adoption of school science teaching by Television would tend to put out of work Science teachers, just as the music broadcasting has done for many musicians.

The answer to this depends on how the Television method is used and by whom. It might be the means of bringing to many schools a class of teaching they could not otherwise obtain. Each Christmas the theatre of the Royal Institution, London, is filled to overflowing with children and adults eager to hear from some eminent lecturer the latest results in scientific research. Television would enable us to multiply such teaching in a dozen places.

At this point, we may perhaps say a word or two more about the relation of unemployment to invention. In his book " Ways of Escape," Mr. Philip Gibbs has given a tremendous inditement of the Machine as against the Man and in another terrible book, " Tragic America," Mr. Theodore Dreiser reveals the extent to which he thinks unemployment is being caused by the invention of machines in the United States. On the other hand we have a highly successful business man, Mr. Israel M. Sieff, Vice-Chairman of Marks and Spencer, Ltd., who told us in a remarkable broadcast in February that the true cause of unemployment is the want of organisation in business. We have not altered our methods to meet the alteration in conditions of manufacture and there is competition and contest, where there ought to be co-operation and union.

It is not invention or machinery as such which must be arrested or displaced, but the power or mode of using it which must be reformed. It *is* possible a time may come when it will be a criminal offence to invent off one's own bat, as it were, but only allowed by special license to invent certain desirable things. We require more adventure and willingness to get out of the rut and explore fresh avenues of livelihood and employment. There are vast spaces yet in the world where there is room for human beings to live and cultivate the soil.

This brings us to consider the great difficulty involved in breaking new ground or getting new ideas accepted when any one particular form of activity or service has become centralised in a few hands or especially where petrified by becoming a Government monopoly.

Closely connected with this is the enormous influence which wise or unwise legislation can exert on invention or progress in new forms of enterprise. I may illustrate this by my own experiences in the last half century in connection with the inventions of the telephone, the incandescent electric lamp and with wireless telegraphy.

When Morse, Wheatstone, Cooke, Bright, and many others had invented instruments which made electric telegraphy by wire possible, which took place in the early part of the reign of Queen Victoria, Joint Stock Companies began to be formed to work telegraph systems in various parts of Great Britain. This electric telegraph had already shown its usefulness in many ways.

Then, in the early " Sixties " an agitation began to be raised against " monopolies," and it was urged that this new method of communication should not be left to be a profit-making means for private individuals. No account seemed to be taken of the fact that there is a large gap of hazardous expenditure between the advent of even a successful experiment and its conversion into a commercial profit-making business. However, the outcome of the discussion was that the British Government of that day passed Acts of Parliament in 1868 and 1869 empowering them to buy up the plant and goodwill of these original Telegraph Companies for a sum of about £10,000,000 sterling which many considered was beyond their actual value.

In order to protect themselves from possible future v. rivalry by further invention, these Acts were drawn with skill and subtility in such form that they conveyed to the Government not only the monopoly of telegraphy, as it then stood, but any possible inventions which might be made for electric inter-communication conducted for profit in this realm. Thus the outcome of an agitation against the formation of one so-called private monopoly was the creation of a still greater government monopoly. It cannot be denied that there are arguments in favour of certain public services being conducted for the benfiet of the national income and not, for that of a limited part of the nation. That is all very well when there is a profit, but what advantage is it to the nation when that service is conducted at a loss, which loss has to be made up out of the profits of another public service? That is the case at present. The Government Telegraph service is conducted at a loss made up out of the profits of the letter-carrying business of the G.P.O.

Ten years, however, elapsed before it was necessary to consider the position. Then in 1876 Alexander Graham Bell patented the speaking telephone and in 1877 Edison the carbon button transmitter and in 1878 David Hughes gave the world freely the invention of the carbon microphone.

The Bell telephone was a good receiver but a poor transmitter. Edison and Hughes invented good transmitters and Edison had invented the curious chalk-cylinder receiver and modifications of Hughes' microphone were made by Blake, Hunning, Gower, Berliner and others. Two Companies were then formed in London by the Bell and Edison interests respectively to conduct telephony. Bell had clearly foreseen that the principal commercial opening for telephony was in the establishment of telephone exchanges with subscribers who could communicate with each other thereby. Litigation was then pending between the rival Telephone Companies. But the General Post Office flung a bombshell into their midst by asserting that a telephone line was a telegraph within the meaning of the Acts of 1868-69. The rival telephone interests had then to unite against their common enemy. In 1880, the important legal action THE ATTORNEY GENERAL v. THE EDISON TELEPHONE COMPANY of LONDON LTD. was heard in the Courts before Mr. Justice Stephen and Baron Pollock and scientific witnesses were retained on both sides. I myself was at that time a scientific adviser to the Edison Telephone Company and one of the witnesses retained by them.

In spite of the arguments put forward to urge that what the Government bought in 1870 was the Telegraph Companies, plant and business as it then stood and not every possible form of inter-communication by electricity which the human mind might ever invent, the judgment was given against the Companies and in favour of the Crown. The case, unfortunately, never went to the Court of Appeal nor to the House of Lords. The Post Office offered the Telephone Companies a license for 30 years in exchange for a royalty of 10 per cent. on their profits and the Companies accepted these terms as they were not willing to risk their capital in further litigation with the Crown. This omission was a great disaster, for it gave the Post Office that position which in course of time enabled it to control wireless telegraphy, radio-telephony, Broadcasting and Television.

The Edison and Bell Telephone Companies came together, put their possessions into a common stock and accepted the General Post Office as their liege Lord and Master. The G.P.O. undertook to provide and maintain the trunk lines which interconnected the various exchanges and in 1910 or thereabouts took over the whole business of exchange telephony.

All that can be said for it was that it is an industry which must essentially be under one control and that the General Post Office with its remunerative work of letter-carrying can afford to work telegraphs and telephones, even at a loss, whereas it would not be possible for the Companies to do it. The Post Office letter-carrying business made a profit of £11,000,000 last year. On the other hand, Government control of a highly technical and scientific business labours under serious disadvantages. In such industries where invention is constantly making fresh additions and where technical advances are now based on profound scientific and mathematical investigations, the average permanent official in Government departments has not the mental qualities necessary to deal with the problems presented. Men of the highest scientific or inventive ability will not enter the Civil Service or be subject to its regulations and red tape. A limited Company or private firm has to live by its wits and take advantage of every improvement and encourage invention, initiative and activity in all its employed staff. It cannot afford to keep on men who make mistakes or are wanting in useful activity. On the other hand, one has seldom heard of a Government employee in the Civil Service, who was reproved for inactivity or discharged for making a mistake. A young official who puts forward new ideas or aims at better results would not find in general his superiors at all sympathetic.

This was the case with telephony. In the 30 years between 1880 and 1910, the G.P.O. had complete control over telephonic enterprise, yet it not only made no substantial advances but resisted attempts from outside to set it on the right path of progress. Meanwhile it took about 1½ millions sterling from the Telephone Company in royalties.

For instance, in the early days of submarine telegraphy the late Lord Kelvin had given a true theory of propagation of electric telegraph currents along cables. He knew that the changes of current in the cable were not sufficiently rapid in ordinary cable signalling to make it needful to take into account the inductance of the line, but only its capacity and resistance. When, however, telephonic currents came to be considered with their rapid changes the inductance of the line became all important.

An eminent mathematician, Mr. Oliver Heaviside, laid the foundations for a correct theory and proved that an increase in the inductance of the line would in general increase the range of telephony.

The G.P.O. officials had, however, in those days, a crude theory of their own based on an erroneous application of Kelvin's theory. Hence the result was that nothing was done in Great Britain to test out Heaviside's theory in practice. But in the United States, where telephony was not a Government monopoly, Pupin and others had a fair field. Pupin gave a correct theory of the insertion of inductance coils called loading coils in the telephonic line and practical experience showed that this doubled or more than doubled the telephonic range.

In the same manner we received from the United States the invention of the wonderful nickel iron alloy called Permalloy which gave the means of uniform loading of cables and greatly improved both telegraphic and telephonic transmission. The application of the thermionic valve as a telephonic relay or repeater was not first made by the General Post Office. In short telephonic research and invention was not assisted but hindered during its early years by Government Control.

It is satisfactory, however, to note that things are now different. The General Post Office maintains now a very efficient and progressive research Department and its activities have had a very useful effect.

The same story of unwise legislation can be told in connection with the early days of electric incandescent lamp lighting. When Swan and Edison had solved the problem of producing an electric lamp of small candle power and such moderate cost and wattage as to make domestic electric lighting possible and when Companies were formed to undertake this work there was the same outcry against monopolies and the Government of that day in 1882 proceeded to pass an Act of Parliament which was ironically termed an Act to *facilitate* electric lighting. The immediate effect of it, however, was to throttle it and make such conditions that no commercial development was possible. The industry of electric supply was held back in Great Britain for six years until an amending Act was passed in 1888. It may be noted in passing that a very large number of Acts of Parliament are termed "An Act to amend an Act," showing that the original Act was a mistake.

The same type of premature legislation took place in connection with Urban electric traction. The general result of this Government control which arises out of a fear of monopoly is to establish a far more extensive monopoly against which the public are powerless to rebel.

Nothing could illustrate this better than the perfect autocracy which has been established in wireless broadcasting arising logically out of the interpretation placed on words in Acts of Parliament passed 35 or 36 years ago, given solely by two judges in a Court of first instance in 1880 and not confirmed by any higher Court. If the original telephone exchanges had not been declared to be telegraphs within the meaning of the Acts of 1868 and 1869, it might have altered the whole situation. As it is these Acts are held to control not only telegraphy properly so-called but telephony and television if conducted for public service and for monetary consideration.

If some inventor were to discover the means of transmitting tastes or flavours by wire or wireless and to convey to a distance the taste of the turtle soup at a Lord Mayor's Banquet for valuable consideration, would that come within the range of the telegraph Acts aforesaid?

We may notice in passing the way in which the license fee of 10/- per annum we pay for the use of our wireless receivers is expended. Out of this the General Post Office take 10 per cent. or 1/- and this Post Office charge covers not only the work of collecting the license fee and discovering and prosecuting evadors or wireless pirates but also the loan of the land lines necessary to convey telephonic speech from the broadcast places or studios to the transmitting or radiating centres from which it goes " on to the air."

This 10 per cent. fee does not seem therefore to be exhorbitant for the work done and facilities provided by the General Post Office. Then the Treasury take 4/- for doing nothing at all. You are mulcted of this 40 per cent. merely for the privilege of listening-in on your own receiver. It is in fact an exhorbitant tax on amusement. Nearly another shilling goes to income tax and general revenue. Thus the Government take 5/5 out of your 10/- and 4/7 goes to the B.B.C. Of this 2/6 is for the programmes but as this includes the B.B.C. Officials' Salaries in arranging them, the conclusion is that hardly more than one fifth of your 10/- really reaches the musicians and performers who give the music we pay to hear. The Engineering Department who attend to the machinery of the broadcast take 1/- nearly out of the 10/-.

Returning then to the question of Legislative Control of Invention, we have seen that the drafting of the Telegraph Acts of 1868/69 gave the Government control of the Telephone Exchanges in 1880 the possibility of which had not been foreseen in 1869. Hence when radio-telegraphy came into being in about 1899-1900 and business communication from ship to shore and vice-versa was achieved that also was brought under Government Control by the Wireless Telegraph Act of 1904 and subsequent Acts. Accordingly when radio-telephony became possible by the invention of the three-electrode valve and the discovery of its power of generating continuous oscillations, that also became the subject of legislative control.

About 1923 or rather later wireless broadcasting of music was begun by the Marconi Company from their works at Chelmsford as a private venture novelty rendered possible by the sale of simple crystal or valve receivers. This developed a little later into the Broadcasting Company.

The great attractions of this new entertainment of picking up music " from the air " by private receivers which began to be put on the market, caused attention to be drawn to the immense possibilities of this new means of publicity and resulted in the formation of the British Broadcasting Corporation in 1926 which though not strictly a Government Department had yet granted to it a Charter for 10 years, and was placed under the control of a small Board of Directors. This Charter will come up for renewal or revision in 1936.

The Chairman of the Board is the Rt. Hon. J. H. Whitley, who was Speaker of the House of Commons from April, 1921, to June, 1928, and was appointed Chairman of the B.B.C. in 1930. The Director General is Sir John Reith, to whom the credit of the organisation of broadcasting chiefly belongs.

It has become clear, however, in the last two or three years that this now highly developed public service has grown into an instrument of enormous power and influence and the question has arisen how far it may become the master rather than the servant of the public.

With the vast improvements which have taken place in the thermionic valve giving us means of radiating hundreds of horse-power in the form of electric waves and modulating this by microphones and picking it up everywhere by radio receivers and loud-speaker telephones; we have had created a means by which a single voice can make itself heard over the whole country and the most complicated music reproduced over large areas with amazing perfection. The Control of this powerful machine has been placed in the hands of very few persons. It is they who can decide what shall be broadcast in speech or music, what opinions, thoughts and arguments shall be disseminated and who are the persons who shall give them out. Against their decisions there is no appeal and although the public who listen-in could theoretically make their desires felt by not renewing their licenses, yet owing to the complete absence of any unanimity between the vast multitude of nearly six million license holders there is no possibility of exercising it.

A speaker who is allowed to broadcast now can exert an effect on public opinion far greater than any M.P. can produce by a speech in the House of

Commons and far before that of any writer of a letter in the daily papers. Any audience that the human voice can directly address in the largest of halls is as nothing compared with the audience a wireless broadcaster can reach without exertion. The Directors of the B.B.C. have in short an uncontrolled monopoly and one moreover of which the control rests in the power of an extremely small group of individuals. They control not only professions such as that of musical soloists, but also invention, as they alone can decide what wave lengths shall be used and the time and nature of the emission, for instance that of Television images.

This monopoly is in a certain sense inevitable and necessary because there cannot conveniently be a multiplicity of broadcasting agencies, and the only alternative to our British system is that of the hiring out of broadcast facilities to those who use it, partly at least, for trade advertisement as in the United States.

There is, however, a widespread opinion that some means should be devised by which public opinion can be brought to bear immediately and effectively on the operations of the B.B.C. and that whilst not interfering with details or practical management can yet express itself on broad general principles. This could perhaps best be done by having a Court of Appeal formed of representatives elected by various public bodies which are themselves representative of various sections and ranks of the public. Such body should not consist of too few members to prevent in any case a few dominating minds securing control. Representatives of all classes of listeners-in should be included. It would be a Court of Appeal on such important questions as the scope of political broadcast speeches, especially those concerned with great questions of policy. Also such questions as the degree of employment of foreign musical talent to the exclusion of British and of the discussion of "live" public questions and broadly of the character of the speech and discussion broadcasts and any other topics on which there are strongly opposed opinions, so as to secure that all sides of them, and not merely one side selected by the B.B.C. governing body, should have a hearing.*

I myself had to make a protest on one occasion against the one-sided advocacy of a very disputed question, viz., the origin of the human race. So far the B.B.C. has done its difficult task of meeting very diverse requirements fairly well but some safeguards are necessary to limit its autocracy.

As regards invention generally, I think one needed reform is an extension of the patent protection period. At present, unless specially extended by an application to the Courts a British Patent lasts only for 14 years. But experience shows that a very large proportion of this time elapses before an invention can be translated into a commercial process, and even then may be far from a profit-making enterprise. It would give a greater chance if this period was extended to 17 or even 21 years. It is now 17 in the United States.

Then as regards the question of Government Control; under the very wide interpretation already given of the Telegraph Acts of 1868 and 69, there ought certainly to be a reconsideration how far these Acts ought justly to be interpreted to cover Television. Should an Act of Parliament in any case be so framed as to control inventions, the possibility of which were not dreamt of at the time these Acts were drafted? As well might they be framed to control any possible realisation of the Robot World of the future, which the exuberant scientific imagination of Mr. H. G. Wells outlines to us. The members of the Television Society are all labourers in a new and fruitful field of work. Mr. Baird's great pioneer work has shown the way to success. The labourers are now many and the opportunities are manifold. Let me wish them all success and conclude with the official motto of University College, London:

CUNCTI ADSINT, MERITÆQUE
EXPECTENT PRÆMIA PALMÆ.

Which as regards the Television Society may perhaps be translated very freely as follows:—

Let as many join up as possible and let the rewards be to those who really deserve them.

* As an instance of the present uncontrolled autocracy of the B.B.C., we may notice the recent attempt to force the unwanted and useless novelty of the 24-hour clock on the public. It is a cardinal principle of British Institutions that those who "pay the piper shall call the tune." But in the case of the B.B.C., the 6 million listeners who provide the income of a million and a half sterling of the B.B.C., have no power whatever in determining what tune shall be played or who shall play it.—Added June 16th, 1934.

Report of the Sixth Annual Business Meeting

The sixth annual General Meeting of The Television Society was held at University College, London, on Wednesday, March 14th, 1934, at 6.30 p.m. The President, Sir Ambrose Fleming, M.A., D.Sc., F.R.S., occupied the chair, and was supported by Dr. Clarence Tierney, F.R.M.S., Chairman of the Council, and other members of Council and the Officers. Apologies for absence were read, including one from Mr. W. G. W. Mitchell, Editor of the Society's *Journal*, and then the minutes of the last annual meeting were read and confirmed. Referring to the Annual Report presented by the Council, a draft of which had been circulated to all members of the Society, Dr. Tierney suggested that this might be taken as read, subject to such comment as members might wish to make. He referred to the satisfactory progress of the Society, and the exceedingly fine attendances at the monthly lectures and meetings throughout the session.

Mr. Wm. C. Keay, the Honorary Treasurer, presented the audited accounts and said he was glad to observe that the Society's expenditure had not exceeded its income for the year; in fact there was a favourable balance, but that had not been secured without the strictest economy, aided by the efforts of all the Officers, who had given their time freely and without any item for their expenses. He deplored the fact that many members were still in arrears with their subscriptions as this prevented development and obstructed smoothness in the production of the Society's publications.

Mr. L. B. Friedman sought further information regarding The Index of Literature referred to in the Annual Report. In reply, Dr. Tierney, said that he knew that Mr. G. P. Barnard, who was in charge of the Index, had made serious progress, but he much regretted that in Mr. Barnard's absence he could give no definite information.

The adoption of the Annual Report and Accounts was proposed by Mr. L. B. Friedman and seconded by Mr. D. H. Byron, and carried unanimously.

The election of Officers and Council resulted in the following being asked to take office:—

President—

Sir Ambrose Fleming, M.A., D.SC., F.R.S.

Vice-Presidents—

Ll. B. Atkinson, Esq., M.I.E.E.
Professor Magnus Maclean, M.A., D.SC., LL.D.
Professor J. T. MacGregor Morris, M.I.E.E.
W. T. Patrick, Esq., J.P.
Sir John Samuel, K.B.E., LL.D.
Clarence Tierney, D.SC., F.R.M.S. (Chairman of Council).

Honorary Fellow—

John Logie Baird, Esq.

Council—

A. H. Bennett, Esq., M.I.E.E.
G. P. Barnard, Esq., B.SC., GRAD.I.E.E.
Professor F. J. Cheshire, C.B.E., A.R.C.S., F.I.P.
R. W. Corkling, Esq., F.P.S.
J. J. Denton, Esq.
H. M. Dowsett, Esq., M.I.E.E., M.I.R.E.
E. L. Gardiner, Esq., B.SC.
Wm. C. Keay, Esq.
H. H. Hope, Esq.
E. G. Lewin, Esq., M.SC., A.INST.P.
T. M. C. Lance, Esq., A.M.I.R.E.
W. G. W. Mitchell, Esq., B.SC.
S. R. Mullard, Esq., M.B.E., M.I.E.E.
R. R. Poole, Esq., B.SC.
J. C. Rennie, Esq., B.SC., M.I.E.E.
E. Phillips, Esq.
C. Tierney, Esq., D.SC., F.R.M.S.
E. H. Traub, Esq.
Capt. B. S. Tuke.
Capt. R. Wilson.

Honorary Treasurer—

Wm. C. Keay, Esq.

Honorary Secretaries—

J. J. Denton, Esq. and W. G. W. Mitchell, Esq.

Messrs. Finnie Ross and Co., Chartered Accountants, were re-elected as Auditors, the proposition being made by Mr. E. H. Traub, seconded by Mr. P. C. Philpot, and carried.

On the motion of Mr. D. Feldman, seconded by Mr. R. Jeffcock, the Officers and Auditors, and the Council were thanked for their services to the Society.

Mr. R. W. Corkling proposed and Mr. H. H. Hope seconded a very cordial vote of thanks to Sir Ambrose Fleming and to Dr. Tierney for presiding, after which the President delivered the Presidential Address.

Sixth Annual Report of the Council and Balance Sheet

PRESENT POSITION.

Last year, in the annual report, your Council had occasion to refer to a period of unprecedented activity in the progress of television. A definite television service, using 30 lines, had been working since March, 1932. Transmissions lasting one-half hour, four evenings a week from 11—11.30 p.m. were arranged by the British Broadcasting Corporation in agreement with the Baird Company and employing the Baird process, and although it was made clear that the agreement was to terminate after a period of two years, i.e., on March 31st, 1934, it was generally felt that television had then reached a stage when it was more than a mere scientific novelty. During 1933, this service has been much improved, both in the actual technique employed and the method of staging and presenting the various items. At the end of the year 1933, the number of such television transmissions was still limited to four evening transmissions at 11.0 p.m., a state of affairs which do not conduce to vigorous or rapid progress. Dealing with this first difficulty, your Officers have not failed in what they considered to be their duty to get such embarrassing lack of facilties improved, and they have endeavoured to press this matter on the attention of the responsible officials of the B.B.C., since it would be regrettable in the interests of future development and progress if the already scanty transmission service was still further curtailed.

During the year, a matter of great technical importance has been brought into prominence, which must have important influences on the immediate future of television. A storm of controversy has arisen over the question whether low definition television (say 50 lines and under per picture) should not give place to high definition pictures of 120 lines or more. In view of the success of the latter experiments in Germany, added support was given to this aspect of the problem in certain quarters over here. It may be said, at once, that such high definition television pictures of 120 lines and more can be successfully transmitted and received over suitable channels. The question of providing a television *service* of high definition pictures using the ultra short waves for transmission, seems to warrant further experiment and research.

It is desirable at this stage to note that the question of high or low definition television are services which need not necessarily be mutually exclusive, and might well be developed concurrently, thus affording the essential facilities for science workers, both amateur and professional, to continue their researches.

LECTURES AND MEETINGS.

The monthly meetings of the Society held in London during the session have been well attended. Many of the lectures were accompanied by practical demonstrations upon the subjects dealt with, and the discussions which have followed have proved of great value and instruction to workers.

The thanks of the Society are due to the undermentioned for their communications, which have contributed so largely to the success of the session.

Once again the Society has to record with pleasure and gratitude the continuance of the facilities so kindly granted by Professor Andrade, Quain Professor of Physics, and the authorities of University College, London, which have enabled the Society to hold its monthly meetings at the College throughout the year.

Jan. 11th.—" A New Television System." Lecture by E. H. Traub (Fellow).

Feb. 8th.—" Gas Discharge Tubes and their Application to Television." Lecture by N. L. Harris, B.Sc., G.E.C. Research Labs.

March 8th.—" Some Aspects of Television Reception." Lecture by T. H. Bridgewater, Grad. I.E.E., A.M.I.R.E. (Fellow).

April 5–6th.—Fourth Exhibition of Television and Photo-Electric Apparatus at Imperial College of Science, London.

May 10th.—" The Design of Television Transmission Equipment." Lecture by J. C. Wilson (Baird Laboratories).

Oct. 11th.—" Television at the 1933 Berlin Radio Exhibition." Lecture by E. H. Traub (Fellow).

Nov. 8th. — "Ultra-Short Wave Television." Speakers: R. W. Corkling, F.P.S. (Fellow), E. C. S. Megaw, B.Sc., D.I.C. (G.E.C. Research Labs.), E. L. Gardiner, B.Sc. (Fellow), L. B. Friedman, Grad. I.E.E. (Fellow), and others.

Dec. 13th. — "Electro-Optics in Television." Lecture by L. M. Myers (Fellow).

Feb. 22nd.—Visit to the Television Studio at Broadcasting House, London.

June 14th. — Visit to Marconi Works at Chelmsford.

The thanks of the Society are hereby conveyed to the Governors of the British Broadcasting Corporation and to the Directors, Works Manager and Research Manager of Messrs. Marconi's, through whose courtesy and consideration these visits were not only made possible, but were thoroughly enjoyed and appreciated.

MEMBERSHIP.

Unfortunately quite a number of members are still in arrears with subscriptions, due to the depression, as evidenced by many letters received. It would considerably minimise the work of the Hon. Secretaries if members would realise that all subscriptions are due on the 1st of January of each year, and so save the necessity and expense of sending out reminders. It should also be noted that members in arrears for two years are "written off" according to the rules of the Society, and that only the paid-up membership can be included in the new list of members.

The live membership of the Society, which means the paid-up members, at December 31st, 1933, was 267, as follows: Fellows 108, Associates 126, Student Members 33, while 48 New Members joined and 13 resignations were received in the same period. These latter are mostly accounted for by inability to pay arrears or to maintain subscriptions.

PAPERS AND PUBLICATIONS COMMITTEE.

As usual, this committee has been concerned with the routine work associated with the production of the *Journal* of the Society.

Members and others are invited to forward original papers to the above committee in order that they may be approved as papers for the lecture evening, or for publication in the Society's *Journal*.

The *Journal* continues to enjoy universal circulation as an authoritative work of reference on current matters relating to Television, its development and application

RESEARCH COMMITTEE.

Consideration has been given to definitions and symbols, and assistance to members and others who have sent in their enquiries and stated their problems.

Members of this Committee have also rendered assistance in connection with lectures given in various parts of the country.

The work in connection with the development of an index of literature has also occupied much time and attention, and the Secretary reports that definite progress has been made in the compilation of the index, which it is hoped to publish as soon as the funds allow.

EXHIBITION.

The Society organised a very successful Exhibition of Television and other photo-electric apparatus—the fourth—on April 5th and 6th at the Imperial College of Science, London. During the nine hours when the exhibition was open to the public, no fewer than 3,000 people attended. Sir Ambrose Fleming, Kt., President, opened the exhibition and special ultra-short wave television transmissions on 7·75 metres were kindly provided by the B.B.C. The latter went to considerable trouble, through their Television Programme Director, Mr. Eustace Robb, in arranging suitable programme material for these special transmissions, which were successfully received. The Society was fortunate in securing the active co-operation of many firms of standing, while working television exhibits were provided by Messrs. Marconi, Messrs. Baird Television and the Wilson Laboratories, among others. There were over 30 individual exhibitors and a comprehensive Catalogue of the Exhibits was issued.

GENERAL.

Further additions have been made to the Society's lantern slide collection. These have been lent freely to various lecturers for lectures at Technical Institutions, Public Schools, Scientific Societies and Public Halls throughout the country. From such lectures, many of our new members have been recruited, and the objects of the Society have been furthered in promulgating the technics of Television.

The rapid development of the Cathode Ray Oscillograph is ensuring the advance of Cathode Ray Television, and is stimulating the interest of various learned societies. Members are advised to follow the various papers as published, and to keep in touch with one another through the Secretary of the Research Committee, in order to aid the advance of this promising field of development.

The Application of the Cathode Ray Tube to Television*

By G. PARR and T. W. PRICE

SUMMARY.

The modern low voltage Cathode Ray Tube—the production of the line screen and the electrical circuits required for it—a new development in electrical scanning circuits.

Modulation of the beam to produce the image—sources of distortion in the tube itself and in the receiver.

High tension and low tension supplies for the tube—operation of the tube from A.C. mains.

A great deal of the subject matter of this present paper was omitted at its reading before the Television Society in January last, but has now been included for the sake of completeness. Simultaneously with the development of a low voltage cathode ray tube in the Edison Swan Company's works, its application to the reception of television was investigated with a view to designing a simple and economical circuit which could be made up from ordinary components and would require the minimum of adjustment.

The use of a cathode ray tube in television involves two considerations; the production of the line screen, and the modulation of the beam to give light and dark gradation as it traverses the screen.

The modulation of the beam, dealing with this point first, is made possible by the focussing characteristic of the tube. Referring to *Fig. 1*, the focussing of the beam is accomplished by adjustment of the negative bias applied to the shield S surrounding the cathode. For a given anode potential there is a definite value of shield bias which produces a field sufficient to squeeze the electrons in a compact jet through the hole in the anode. The intensity of the fluorescent spot, which is dependent on the number of electrons arriving at the screen is proportional both to anode potential and to shield potential within certain limits. For a given anode potential, the intensity-bias curve follows approximately the shape shown in *Fig. 1a*, which is similar to the I_A V_G curve of the ordinary triode. An increase in negative shield bias cuts off the beam completely, and, of course, reduces the intensity

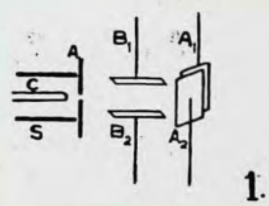

Fig. 1—Diagramatic sketch of electrodes of Cathode Ray Tube.

to zero. A decrease in bias results in increased intensity until the beam at the same time commences to spread and the spot loses focus. The region of the curve between the crosses therefore represents a condition where the intensity of the beam is reasonably proportional to variation in bias, and to modulate the beam it is only necessary to superimpose the television signal on the normal shield bias value, while the beam is traversing the screen.

* A Paper presented at a meeting of the Society held at University College, London on Jan. 17th, 1934.

THE SCREEN.

The majority of tubes in use have green fluorescent screens made by coating the end of the glass with zinc silicate or other compounds. The principal advantage of the zinc silicate screen is its " fluorescent efficiency," i.e., the intensity of spot is good with a moderate anode voltage or electron velocity. Screens made of calcium or cadmium tungstate give a bluish white fluorescence which is superior actinically but which requires a higher anode voltage for a given intensity. It is difficult to draw comparison between screens of varying actinic value and efficiency, owing to the difficulties of accurate measurement of light intensity.

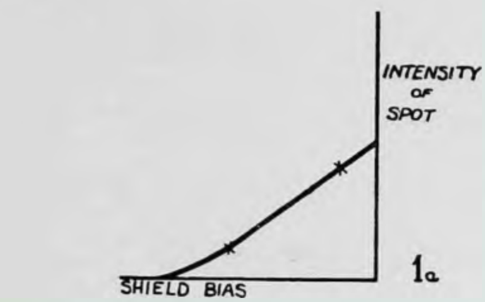

FIG. 1a—Approximate relation between shield bias potential and spot intensity.

For 30-line television work, the green screen is not so unsuitable as might be supposed, since the colour is soothing to the eye, and in addition there is a slight trace of " After-glow," or persistence of the fluorescence. This tends to reduce the harshness of the picture, and as the glow only persists for a small fraction of the picture time, it does not cause appreciable distortion except in very rapid movements of the image. Zworykin, in his recent paper on Cathode Ray Television,* gives a curve of decay of luminescence of zinc silicate compounds, and states that for a picture frequency of 20 per second, the effective brilliance should die out in 1/20th second. If less after-glow than this is required, the blue-white screen is the better medium.

As a matter of interest, it may be mentioned that screens having an " after-glow " of several seconds duration have been made, and these are used in electro-cardiography and allied problems requiring the observation of slow recurring impulses.

With high anode voltages there is a liability to burning of the screen at one point if the spot is allowed to remain stationary for long periods. This is inevitable, since the whole of the beam energy is dissipated over an area of say ·2 sq. mm., and as a result the compound forming the coating is changed physically. The evidence of this is a discolouration on the screen which renders that particular area inactive. As a precaution, the spot should never be allowed to remain stationary on the screen for long periods.

* *J. Inst. Electrical Engineers*, Vol. 73, No. 442.

DEFLECTING THE BEAM.

The beam is deflected by the two pairs of parallel plates marked in *Fig. 1* as A_1 A_2, B_1 and B_2. The requirements of the television screen are the deflection of the beam in the vertical plane at a given frequency depending on the number of lines, and a horizontal deflection at a speed equal to the picture frequency. Both these movements must be linear, *i.e.*, the beam must cover equal distances on the screen in equal increments of time. At the end of the traverse of the beam, it must return to its initial position as rapidly as possible to avoid encroaching on the next frame.

The fundamental circuit in the production of a linear traverse of the beam is that shown in successive stages of development in *Fig. 2*. The simple condenser resistance circuit shown in (*a*) deflects the beam slowly across the screen as the condenser charging potential rises, and when the neon lamp '*N*' strikes the beam rapidly returns to its initial position owing to the immediate fall of potential across the discharging condenser. The drawbacks of this simple circuit are twofold:—

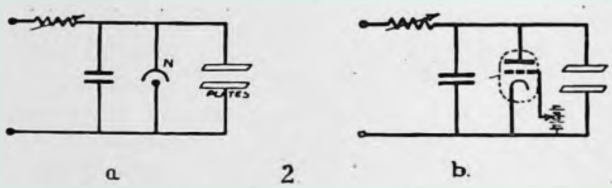

FIG. 2a—Basic circuit for producing a multi-line screen on the Cathode Ray Tube.

FIG. 2b.—The addition of a Mercury Vapour Relay to the same circuit to improve its characteristics.

(1) There is insufficient difference in potential between the striking and extinguishing potentials of the neon lamp to give a satisfactory length of deflection of the beam.

(2) With ordinary values of H.T. voltage, the charging curve of the condenser is exponential even over the region of working voltage change.

Drawback No. 1 is overcome by replacing the neon lamp with a mercury vapour relay, the circuit then being as *Fig. 2b*. The theory of this device is well known. The striking potential of the relay is dependent on the initial bias applied to its grid, and with the ordinary commercial type of relay the striking voltage is raised by approximately 20 for each volt of bias applied.

The lowest value of striking voltage is that of the ionisation of the mercury vapour (10–15), and below this value the discharge is not maintained. Accordingly, if the relay is once conducting, the discharge will persist until the anode potential has fallen below 10–15 volts, irrespective of alteration of grid potential.

The actual range through which the voltage will have to vary is determined by the sensitivity and dimensions of the tube and by the proportion of the picture frame.

The sensitivity of the tube in turn depends on the anode voltage, for a given construction of electrode system.

Mathematically,

$$\text{Deflection} \propto (l/2d) \times (E/E_a) \times L$$

(l and d being the length and distance apart of the deflectors; L, the beam length; E_a the anode voltage, and E the deflecting potential), from which it will be seen that the deflection is inversely proportional to the anode voltage. It is usual to operate the tube at about 1,000 v., to obtain sufficient intensity for the image, and under these conditions the sensitivity is of the order of ·3 m/m per volt. Assuming an effective screen diameter of 10 cms., a 7 × 3 picture requires a beam travel of 10 cms. vertically and 4·3 cms. horizontally, corresponding to deflecting potentials of 330 v. and 140 v. respectively.

To obtain these deflecting potentials in the time-base circuit, the bias of the respective relays is set at approximately 16 v. and 7 v. The condensers will then charge to the values of potential given above, before the relay strikes and the beam returns to its initial position.

It would be quite impracticable to utilise the resistance-condenser circuit of *Fig 2b* with moderate values of H.T. voltage on account of drawback No. 2, and some form of linear charging current device is essential to obtain an uniform increase in potential across the condenser. For this purpose, the resistance can be replaced by either a saturated diode or some other constant current device such as a screen grid or pentode. The effect of this is briefly as follows: As the potential across the condenser rises, the IR drop across the series resistance falls, the total of the two potentials always equalling the H.T. applied volts. In a plain resistance, this results in a reduction of charging current as the condenser charges, giving the exponential charging curve. In the case of a saturated diode, the charging current is unaffected by a reduction of potential drop across the valve within wide limits, and the condenser continues to charge at a uniform rate.

The circuit diagram of the original double time-base used in early experiments is shown in *Fig. 3*, using saturated diodes operated from 2 v. cells. The respective merits of diodes and

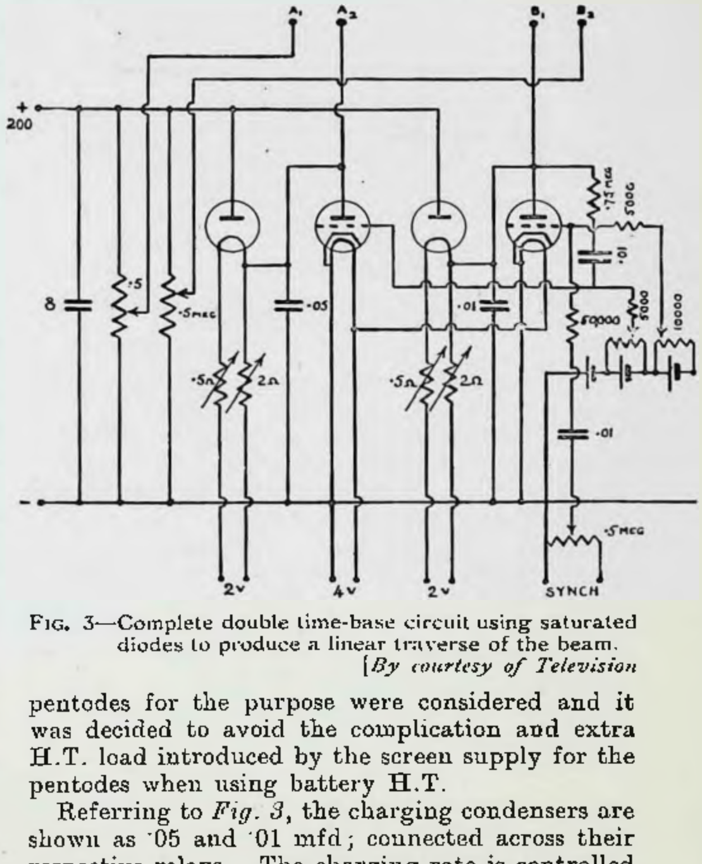

FIG. 3—Complete double time-base circuit using saturated diodes to produce a linear traverse of the beam.
[*By courtesy of Television*

pentodes for the purpose were considered and it was decided to avoid the complication and extra H.T. load introduced by the screen supply for the pentodes when using battery H.T.

Referring to *Fig. 3*, the charging condensers are shown as ·05 and ·01 mfd; connected across their respective relays. The charging rate is controlled by the impedance of the diode, which is varied by the filament rheostats (coarse and fine adjustment). One of each pair of the deflector plates of the tube is connected to the anode of the relay and the opposite one is joined to the slider of a potentiometer connected across the H.T. supply. This enables the potential of the deflector with respect to the anode to be adjusted, and serves to centralise the frame. The remaining details of the circuit will be discussed under "Synchronising."

For 30-line reception this time-base worked well, but proved difficult to keep in synchronism for long periods without attention. The trouble was eventually traced to slight variations in the emissivity of the diode filaments. Although of pure tungsten (bright emitters!), slight traces of thorium impurity in the filament tended to give the diodes varying emission at low temperatures

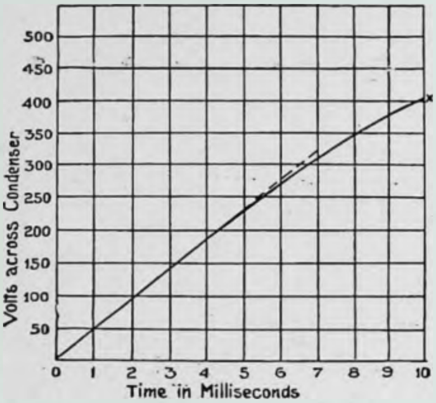

FIG. 4—Charging curve of condenser (·01 mF) in series with a 2 megohm resistance.

[*By courtesy of Television*

with consequent fluctuations in time-base speed. It would appear impossible to overcome this trouble, which would be exaggerated at higher speeds of scan, and accordingly the original circuit of *Fig. 2b* was reverted to, but with a much higher value of H.T. voltage. Under these conditions, it is possible to make use only of the initial portion of the exponential charging curve of the condenser, and by choosing the values of series resistance and capacity so that the relay discharges before the curve departs from linearity, a very satisfactory time-base is produced. The curve of *Fig. 4* is calculated according to the expression for the charging of a condenser.

$$V = E(1 - e^{-t/cr})$$

for a given value of C and R, and it will be seen that the period of 1/375th second is reached before the curve assumes the exponential form. The total H.T. voltage applied to the time-base is approximately 1,000, which necessitates careful precautions in wiring and in insulation, but otherwise no difficulty is experienced. Should the mercury relays become open circuited, the condensers will, of course, charge to the full H.T. volts, and therefore should be capable of withstanding this voltage. The 2-meg. variable resistances were supplied by the Reliance Manufacturing Co., who also wound the ½ ohm. and 2 ohm. variable resistances for the cathode circuit.

H.T. SUPPLY FOR TIME-BASE.

Since the mercury relays are indirectly heated, it is possible to operate the time-base from rectified A.C. without introducing serious interference. The current taken by the circuit is low (5–8 mA) and a standard 80 Henry smoothing choke is used in conjunction with 2–4 mfd. 1,600 v. condensers. The half-wave rectifier was an Ediswan MU. 1 mercury vapour filled. Considerable trouble was experienced in obtaining a valve holder to withstand about 2,000 v. between cathode and anode sockets, and eventually the valve was mounted "naked," the connections being soldered direct to the pins. The circuit of *Fig. 5* (*a*) shows the H.T. unit and *5* (*b*) the H.T. rectifier unit for supplying the cathode ray tube.

TUBE SUPPLY.

The tube is supplied from a standard half-wave H.T. rectifier circuit employing a high voltage diode. Automatic bias for the shield is obtained from a high resistance connected between cathode and H.T. –. The anode current taken by the tube is only of the order of 20 μA, a feature which simplifies the smoothing circuit, but which necessitates a high value of self-bias resistance. A shunt resistance of 10 megohms is connected between +H.T. and tube cathode to ensure satisfactory cut off of the beam.

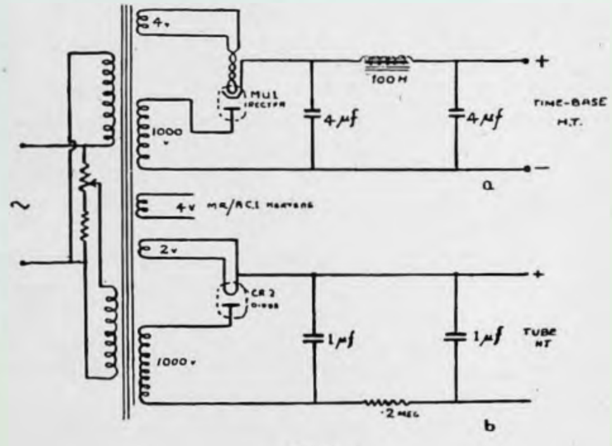

FIG 5

FIG. 5—H.T. supply for the double time-base and for the Cathode Ray Tube. The latter current requires less smoothing owing to the small current taken.

In H.T. mains units the problem of interference has always to be considered. With soft tubes, owing to their high sensitivity, it is usually impossible to mount the mains transformer nearer the tube than 2 feet, owing to magnetic influence on the beam.

The cathode can in some cases be fed from raw A.C., but this is not advisable if the utmost freedom from interference is desired, and in the apparatus constructed a 2 v. cell was used for the cathode supply.

Experiments are at present in progress with a view to enabling the tube to be operated completely from A.C. mains without interference, and it is probable that a self-contained unit can be produced to include the exciter unit with the time-base.

The modulating signal applied to the shield of the tube is fed in to a 30,000 ohm. potentiometer included in the automatic bias circuit. The extra resistance introduced by the auto-bias potentiometer itself is by-passed by a 2 mfd. condenser shown in the circuit diagram of *Fig. 6.* It should be noted that the input is completely isolated from the tube by two ·1 mfd. 1,500 v. working condensers.

"ORIGIN DISTORTION."

With low-voltage cathode ray tube in which a trace of gas is present to assist focussing, a slight defect is present which is usually termed "origin-distortion" or "threshold effect." The presence of ions in the path of the beam due to collision with the gas molecules requires a definite initial potential to be applied to the deflector plates to neutralise their charge before the beam itself can be deflected. This means that the beam deflection is non-linear with respect to deflecting voltage over a range of about 10 v. either side of zero. In practice, the origin distortion is shown by a narrow horizontal band of slightly greater intensity across the middle of the television screen and by a vertical line of greater intensity in the centre of the screen.

The origin distortion can be shifted laterally by means of two magnetic deflecting coils mounted in line with the rear deflector plates, the whole frame

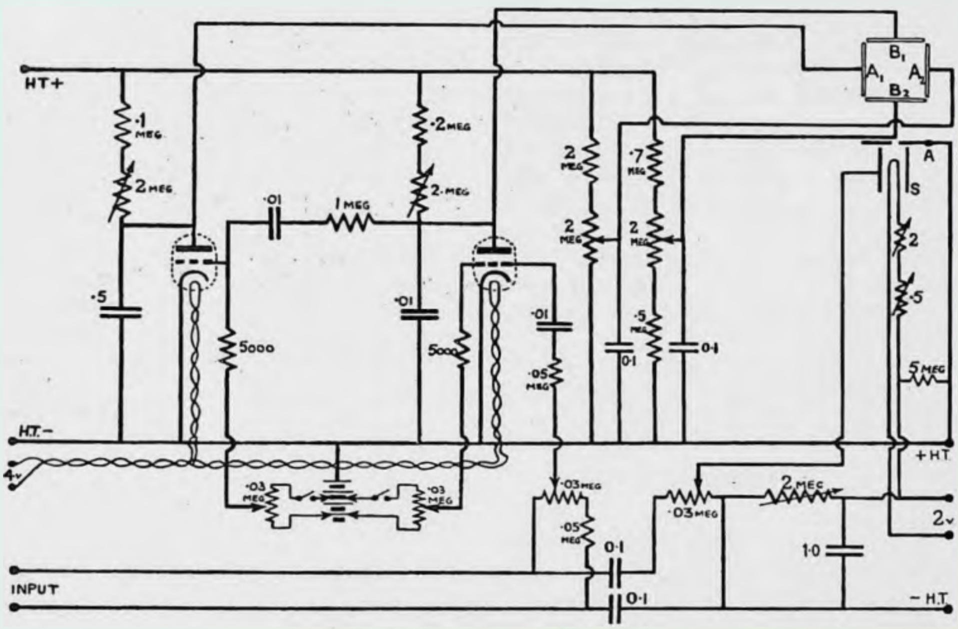

FIG. 6—Complete double time-base circuit using resistances instead of diodes and a high value of H.T. supply. The circuit for exciting the tube is shown on the right.

It is conventional to consider the anode of the tube as the "zero potential" point, and the cathode is therefore "live" by 1,000 volts. The negative of the time-base supply is connected to anode.

The complete circuit of the final development of the double time-base and tube supply is shown in *Fig. 6,* and thus should be compared with the diagram of *Fig. 3,* noting that in the latter the cathodes of the diodes are at different potentials and therefore necessitate separate L.T. cells.

being restored to centrality by a bias applied to one of the deflectors in the manner shown in *Fig. 6.* With hard tubes, of course, the origin distortion is not present, neither is it encountered if the beam is deflected solely by magnetic fields.

SYNCHRONISING.

Synchronisation of the time bases with the television signal is accomplished by feeding a small potential from the output circuit to the grid of the 375-cycle mercury relay in order to ensure that the condenser discharges regularly every 1/375th second. The action of the synchronising signal will be seen from the diagram of *Fig. 7*, in which the vertical scale has been taken to represent voltage across the condenser and relay grid voltage, and the horizontal scale represents time.

Assume that the constants of the condenser-resistance circuit are such that the condenser is discharging every 1/370th sec., *i.e.*, the time-base is "slow." Normally this would result in a slow drift of the picture in the vertical plane, although if the horizontal speed were correct, the picture would still be recognisable. Incidentally this is an interesting difference between the cathode ray system of viewing and the mechanical—it is possible for the picture to shift either in the vertical or in the horizontal direction independently, and a loss of synchronism does not necessarily mean a chaotic picture.

To resume—the lower straight line in the diagram represents the normal grid bias of the relay, and on this is superimposed every 375th sec., a kick from the synchronising impulse. This has been represented by a peak of momentary duration for the sake of convenience, although it is more complex than this in practice. Provided that the phase and polarity of this kick are correct, it will result in a momentary lowering of the grid bias of the relay, which will cause the discharge to start, although the condenser is not fully charged. The condenser is thus compelled to discharge every 1/375th second by the impulse.

If the time-base is running "fast," *i.e.*, if the condenser is discharging every 1/400th second, it will be on its charging rise at the arrival of the synchronising impulse and this will be ineffective. The synchronising action therefore works best on a slow-running time-base.

In practice, two points complicate the action of the synchronising—the phasing and the magnitude. On reflection, it will be appreciated that the impulse can occur at any point on the charging cycle, its incidence being purely a matter of chance. However, this can be allowed for in the actual reception by allowing the picture to "slip a frame" or so until the synchronising signal establishes control.

The magnitude of the voltage applied to the grid of the relay will to a certain extent be controlled by the characteristics of the relay—too small an impulse will not discharge the relay at all, while too large a one will, if the time-base is appreciably out of synchronism, shut it up altogether and shorten the travel of the beam.

ADVANTAGES OF THE CATHODE RAY SYSTEM.

In conclusion it should be pointed out that the system described in this paper was designed for the application of the cathode ray tube to the reception of present day television.

In the design and construction of the circuits, the prime points considered were economy and simplicity. The apparatus, with the exception of the tube and the relays, can be assembled from standard components, and provided reasonable care is exercised there is no risk from the high voltages employed.

The use of the cathode ray tube in experimental circuits has several unique advantages.

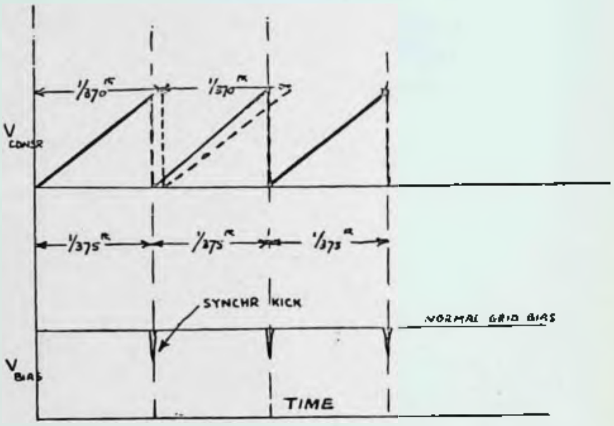

Fig 7.

FIG. 7.—Diagram to illustrate the action of the synchronising control applied to the grid of the relay.

The speed of the time-base is flexible within very wide limits, and if necessary the scanning can quickly be changed from vertical to horizontal.

The energy consumption of the tube is negligible, and for satisfactory modulation the smallest type of power valve is suitable.

The voltage required to synchronise is very low, and the station can therefore fade considerably before the impulse is too weak to affect the scanning speed.

The arrangement is quite silent in operation, as it is completely free from movement of a mechanical nature.

*Review of the Theory and Applications of Photo-electric Effects**

By G. WINDRED, A.M.I.E.E.

SUMMARY.

The paper gives a useful summary in historical sequence of the theory underlying the photo-conductive and photo-electric effects, with a number of interesting applications and a bibliography.

The progress which has recently taken place in the application of photo-electric apparatus has aroused a wide general interest in this subject. Although it is only during the last two or three years that the practical uses of the photo-electric principle have been at all extensive, the first experiments on these effects extend back far into the history of experimental science. For nearly fifty years there has been extensive and continuous research into the numerous problems presented by photo-electric effects. This work has given rise to an extensive literature, which has been contributed to by research workers in America and England and on the Continent, and which is now far too large to be assimilated by any individual worker in this field. There is a consequent difficulty for such workers to keep sufficiently in touch with the main developments of their subject to ensure efficient progress, which must of necessity depend largely upon previous work. For these reasons, it seems desirable to review the salient points of development of photo-electric theory and practice in a manner which will indicate the inter-dependence of past researches and the tendencies of present practice.

It is worthy of note that the greater part of photo-electric research has been undertaken without any intention of applying the results in practice. This research has for the most part taken place in university laboratories, where it has formed a branch of advanced physical research. The combined efforts of a large number of workers in this department of physics have resulted in our present detailed but by no means complete knowledge of photo-electric phenomena. It would have been difficult for any of the early workers in this field to predict any practical use for their results, and there are indeed still many photo-electric phenomena which would appear to have few or no possibilities of practical application. The present requirements of practice employ only a very small proportion of modern knowledge.

The subject of photo-electricity deals with the emission of electrons from a conductor under the action of incident light. (The German term is *äusserer elektrische effekt*, i.e., external electrical effect). There is another effect which is sometimes called photo-electric, although actually it is an example of photo-conductivity, and that is the alteration in conductivity of a conductor with alterations of incident illumination (German, *innerer elektrische effekt*, i.e., internal electrical effect). In the following discussion, we shall retain the historical order by first considering photo-conductivity, the discovery of which preceded by some fourteen years the first observations on photo-electricity.

PHOTO-CONDUCTIVITY.

The best known substance for exhibiting photo-conductive effects is Selenium. This element was discovered by Jons Jakob Berzelius as an impurity in sulphuric acid in 1817 (Schweigg. Journn. 23, 309, 430; Pogg. Annal. 7, 1826, p. 242; 8, 1826, p. 423). The name is derived from the Greek Σελήνη (the moon), on account of the affinities of selenium with tellurium (Lat. *tellus*, the earth), which had been discovered shortly before. There are several allotropic forms of selenium, which may be classified under three headings (Saunders, J. Phys. Chem., vol. 4, 1900, p. 423, gives a bibliography of this question), i.e., (1) amorphous, vitreous and colloidal, soluble in carbon bisulphide, (2) red crystalline, occurring in two distinct forms, soluble in carbon bisulphide, (3) metallic, which is insoluble in carbon bisulphide. It is only

* A Paper presented to the Society on Feb. 14th, 1934, at University College, London.

this last form which is electrically conducting and light-sensitive, the discovery of the latter property being made by Smith and May in 1873, ("Journ. Soc. Telegraph Eng.," vol. 2, 1873, p. 31; *Nature*, Feb. 20, 1873). The principal properties of selenium are as follows:—

Atomic weight, 79·2.
Melting point, 220° C, approx.
Boiling point, 690° C, approx.
Specific heat, 0·084 (crystalline); 0·095 (amorphous).
Linear expansion, $4·9 \times 10^{-5}$ (crystalline).
Specific resistance per cm. cube, 70,000 ohms (crystalline).

It is instructive to compare the last figure with the specific resistance of copper, $1·6 \times 10^{-6}$ ohms, which indicates that the resistance of selenium is about 4×10^{10}, i.e., forty thousand million, times that of copper. It follows that the currents dealt with in photo-conductivity experiments on selenium are of necessity very small.

The first definite experiments with selenium "cells" were made by W. Siemens in 1876. Several other experimenters also took up the subject, and cells of various kinds were developed by Sabine (1878), Bidwell (1880), Graham Bell (1880), Mercadier (1881), Fritts (1883), Righi (1888), Liesegang (1890), Minchin (1895), Ruhmer (1902), and others. It was shown by Sabine in 1878 that an e.m.f. is generated on exposure to light of a voltaic cell in which selenium is used as an electrode. This phenomenon is quite distinct from the photo-conductive effect, and its theory is not clear at present. It was found by Minchin, who employed the arrangement for stellar photometry in 1895-6, that an e.m.f. of 0·03 volt could be obtained by illuminating 0·645 sq. cm. of sensitive surface with a candle placed 274 cm. away. The device is properly referred to as a "cell," but this term has been applied extensively to photo-conductive devices, for which the proper term is "selenium bridge."

Theory of the Photo-conductive Effect.—Many attempts have been made to develop a satisfactory theory of photo-conductivity, notable work in this connection having been carried out by the late E. E. Fournier D'Albe (Proc. Royal Society, A., vol. 89, 1913, p. 75), whose views on the subject now find general acceptance. By utilising the atomic conception of matter, he was able to construct an "ionisation theory," which accords very well with the observed facts. The ionisation theory supposes that the incidence of photons comprising a beam of light produces alterations in the atomic structure of selenium to such an extent as to remove electrons from their normal atomic orbits and add them to the normal number of free electrons which exist under conditions of darkness and determine the dark-conductivity of the material. It follows that the incidence of light upon a selenium conductor will have the effect of increasing its conductivity.

If we consider the ionisation process in detail, it is to be expected that the number of electrons separated from their atoms will be proportional to the intensity of the incident light. The surplus of electrons thus produced will tend to re-combine with the positive ions representing the results of ionisation, and their success in this matter will evidently depend upon the number of ions present. Since the liberation of an electron by the incident light also results in the production of an ion, it is seen that the rate of re-combination will always be proportional to the square of the number of ions. These conditions may be expressed by saying that the rate of change of conductivity, i.e., the rate of increase in the number of ions is—

$$dN/dt = C - kN^2 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where C is the incident light energy, N the number of ions which it liberates, and k is a constant. From this expression, it is seen that the total change of conductivity after time t is—

$$N = (C/k)^{\frac{1}{2}} \tanh (tC^{\frac{1}{2}}) \quad . \quad . \quad . \quad . \quad (2)$$

It will be noted that this expression is of the general form $N = KC^x$, for a given value of incident light energy, and since N represents the change of conductivity $G_1 - G_0$ between the illuminated and dark conditions respectively, we may write for the total change of conductivity—

$$G = G_1 - G_0 = KC^x \quad . \quad . \quad . \quad . \quad . \quad (3)$$

in which K and x are constants of the material. A curve connecting G with $\log C$ will thus represent the characteristic of a selenium detector with appropriate constants.

The condition for stability of resistance under illumination is that the rate of re-combination of ions shall be equal to the rate of their production. Under these conditions, the differential in equation (1) is zero, and therefore $C = kN^2$, so that—

$$N = (C/k)^{\frac{1}{2}} = K\sqrt{C} \quad . \quad . \quad . \quad . \quad (4)$$

indicating that the change of conductivity is proportional to the square root of the incident energy.

The exact mechanism of ionisation by light in selenium has been the subject of several speculations, but there is no general acceptance of any particular theory. It seems reasonable to suppose that the action of photons on the selenium atoms is such as to disturb the dynamical equilibrium of the orbital electrons revolving around the atomic nuclei to such an extent that they describe parabolic or hyperbolic paths and are thus expelled from the atomic structure. The subsequent movement of an electron expelled in this manner will presumably depend upon the electrical forces acting upon the material. The mechanism of photo-conductivity is probably closely similar to that giving rise to thermionic emission. (For a detailed discussion of the various theories, see G. P. Barnard, " The Selenium Cell," London, 1930, Ch. V., " Theories of Action of Light on Selenium.")

We have already remarked that the rate of re-combination of ions is proportional to the square of the number present, and it follows that the process commences rapidly as soon as the light is removed, taking place at an ever-decreasing rate until all the disturbed electrons have returned to the atoms. These conditions correspond to the " dark-conductivity " state, corresponding to the number of free electrons.

Applications of Photo-conductivity. — The possibility of applying the light-sensitive properties of selenium to the performance of useful functions has been recognised for many years, and has received much attention from experimenters of all classes. The modern selenium bridge embodies many improvements on the early arrangements, and is employed extensively in many branches of practice. Chief among its uses at the present time are the control of illumination in accordance with daylight intensity and the counting of moving objects. The applications to stellar photometry, which may be regarded as first indicating the practical value of photo-conductivity, appear to have experienced considerable decline due to the introduction of other methods. It is to be expected that many technical difficulties were encountered in the course of development of a satisfactory commercial form of selenium bridge, and the faults of such devices have formed a source of objection in the past. At the present time, however, it seems that such difficulties have to a large extent been removed, so that for the majority of applications it is possible to employ selenium bridges with the same security against mechnical failure as would apply to modern thermionic valves. The selenium bridge can now be constructed to withstand voltages of the order of 1000 volts, and with a resistance of any value between the approximate limits of half a megohm to 250 megohms. The " dark-current " similarly varies between about 1 milliampere to 250 milliamperes. As an example of sensitivity it may be mentioned that a bridge of 4 megohms resistance can be made to produce a current change of the order of 100 milliamperes between dark and light conditions. Currents of this order are amply sufficient for the operation of sensitive electro-magnetic relays of commercial design, without the necessity of amplifying devices, but in the greater number of practical applications it is customary to include a thermionic valve amplifier.

The selenium bridge has played an important part in the transmission of sound by light, being employed for this purpose in the Photophone of Graham Bell (1880) and subsequently in various similar types of apparatus. (See D'Albe, " The Moon Element," London, 1924, Ch. V—X, for an account of early developments). This work may be regarded as preliminary to modern methods of television, facsimile transmission and the sound film.

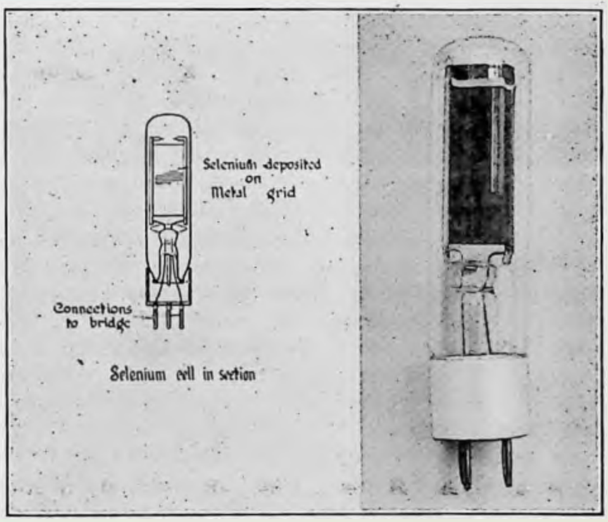

FIG. 1—Typical selenium cell of modern type.

[*Courtesy of General Electric Co.*

It is found that the degree of response, in the form of conductivity change, with a selenium cell varies with the wave-length of the incident light. This effect has been explained by supposing that the outer electrons of the selenium atom lattice have a definite individual natural frequency or period of oscillation, and are consequently more easily disturbed by the action of light of a particular frequency. This property renders possible the comparison of different sources of light or different colours, but the selenium bridge is not so satisfactory for this work as other methods to which we shall presently refer.

PHOTO-ELECTRICITY.

It was found by Heinrich Hertz in 1887 (Wiedemann's Annalen, vol. 31, 1887, p. 983) that the action of light, particularly in the ultra-violet, had an effect on the electrical potential of a body subjected to these rays. This observation received the attention of numerous physicists, including Hallwachs (Wied. Ann., 33, 1888, p. 301), Hoor (Repertorium der Physik, 25, 1889, p. 91), Righi (Comptes Rendus, 106, 1888, p. 1439; 107, 1888, p. 559), and Stoletow (C.R., 106, 1888, pp. 1149, 1593; 107, p. 91; 108, p. 1241; Phys. Rev., Bd. 1, 1892). As a result of these researches, it was found that a negatively charged body lost its charge when exposed to light of short wave length. In the case of a positively charged body no such effects were observed, and the question naturally arose as to why these conditions existed. The solution of this problem, and many others connected with photo-electric phenomena, is due to the experimenters Elster and Geitel (Wied. Ann., 38, 1889, pp. 40, 497; 41, 1890, p. 161; 42, 1891, p. 564; 43, 1892, p. 225; 52, 1894, p. 433; 55, 1895, p. 684), who made a series of comprehensive experiments extending over many years.

The loss of negative charge by a substance subjected to light of high frequency can be explained by modern physical theory as due to the migration of electrons. It is supposed that the incident light energy is able to liberate and expel from the material the electrons comprising the electric charge. The mechanism of this interaction is not fully understood, but the quantum theory allows of a satisfactory explanation of the principal phenomena. It has been found by experiment that the ejected electrons leave the photo-electric substance with a velocity dependent upon the type of material and the frequency of the incident light. It was first shown by Lenard (Ann. der Phys., 8, 1902, p. 149), and confirmed some years later by Pohl and Pringsheim (Verh. der Deutsch. Phys. Ges., 15, 1912, p. 974) and by Millikan (Phys. Rev., 1, 1913, p. 73) that the velocity of photo-electrons is in no way dependent upon the light intensity. The experiments of Lienhop (Ann. der Phys., 21, 1906, p. 281) and Ladenburg (Verh. der Deutsch. Phys. Ges., 9, 1907, p. 165) have also shown that this velocity of emission is also independent of temperature between the limits of 180°C and 800°C.

All metals exhibit the photo-electric effect if light of suitable wave-length is employed. In the case of ordinary metals, however, such as copper, gold and platinum, it is necessary to employ light in the extreme ultra-violet before the effect can be obtained. With the alkali metals, and especially the electro-positive ones, the effect is shown with visible light. There are relatively few suitable metals of this class; they include barium, caesium, lithium, potassium, rubidium, sodium and strontium, as the most generally used for photo-electric work.

Elster and Geitel arranged various light sensitive metals in accordance with their strength of emission as follows:—

Rubidium.
Potassium.
Alloy of Potassium and Sodium.
Sodium.
Lithium.
Magnesium.
Thallium.
Zinc.

It should be noted that this order is the same as in Volta's series for contact-electricity, the greatest photo-electric effect being given by the most electro-positive metals. In general they are chemically very active and accordingly require special methods of preparation. The development of these methods has received attention from Ives (Astroph. Journal, 60, 1924, p. 209), Fleischer (Ann. der Phys., 82, 1927, p. 75), Klumb (Zeits. techn. Phys., 47, 1928, p. 652), Campbell (Phil. Mag., 6, 1928, p. 633), and others.

Theory of the Photo-electric Effect.—Theoretical examination of photo-electric phenomena presents numerous problems for which it is difficult to provide consistent or satisfactory solutions without adopting the methods of modern theoretical physics. The photo-electric effect has consequently provided the physicist with an important subject, of which the major details have already been firmly established by his efforts.

For each particular substance there is a definite frequency of the incident light below which there is no observable photo-electric effect. This is called the threshold frequency of the substance, and is usually denoted by ν. On the basis of modern physical theory, it can be supposed that light-energy takes the form of a shower of light-quanta or photons, each having a definite amount of energy, which the quantum theory of Planck (Ann. der Phys., 4, 1901, p. 553) estimates as $h\nu$, where ν is the frequency of the light and h is Planck's constant, having the approximate value $6{\cdot}55 \times 10^{-27}$ erg. sec. The quantum theory therefore states that the energy of radiation of any kind is dependent only upon its frequency. It follows that light of short wave-length is the most effective from the energy viewpoint, and we should consequently expect this kind of light to give a stronger photo-electric effect for a given substance than would be produced by light of longer wave-length. This is actually borne out by experiment, and we have already noted that for a given substance it is necessary to employ light of more than a certain critical frequency in order to obtain the emission of photo-electrons.

If we suppose that it requires a certain definite amount of energy, say E, to dislodge an electron from its normal location in a material, this dislodgment will occur only when the incident photon has energy of this amount, that is when the condition $h\nu = E$ is satisfied. Owing to inter-atomic and other restrictive forces, a certain additional amount of energy is necessary actually to expel the liberated electron from the boundaries of the substance, so that for this condition we must have $h\nu > E$. Since modern physical theory shows that it is permissible to apply ordinary dynamical theory to a moving electron, we may equate the dynamical energy of the emitted photo-electron to the surplus of energy resulting from the incidence of a photon for which $h\nu > E$ in the following manner:—

$$\tfrac{1}{2}mv^2 = h\nu - h\nu_0$$

This equation assumes that the whole of the surplus energy is used up in endowing the electron with velocity. It accords very well with experiment, and has been used as a means of determining h for different substances. Experiments by Millikan (Phys. Rev., 4, 1914, p. 73; 6, 1915, p. 55) in this connexion have yielded values of $h = 6{\cdot}561 \times 10^{-27}$ for sodium and $6{\cdot}585 \times 10^{-27}$ for lithium. These values are in excellent agreement with those determined from experiments on black-body radiation by Coblentz (Sci. Papers, Bur. Stds., No. 360, 1920) giving $6{\cdot}55 \times 10^{-27}$; on X-ray spectra by Blake and Duane (Phys. Rev., 10, 1917, p. 624) giving $6{\cdot}555 \times 10^{-27}$, and on specific heats at low temperature by Keesom and Kamerlingh—Onnes (Communication No. 147a from Phys. Lab. of Leiden; Verslag Amst. Akad., 1915, p. 335) giving $6{\cdot}59 \times 10^{-27}$. There seems little doubt that the effects are accurately represented by the foregoing theory, but their actual mechanism remains rather obscure, although several theories have been developed to explain photo-electric action. One of these is based on the radiation theory of Bohr (Phil. Mag., 26, 1913, pp. 1, 476), which supposes that in the process of emitting radiation an atom shrinks to a different state. If we assume that the process is reversible, the incidence of a quantum of energy $h\nu$ on the atom will result in its expansion owing to the absorption of this energy. Experimental proof of this assumption has been provided by observations on line spectra by Hartmann (Phys. Zeits., 18, 1917, p. 429), Franck and Hertz (Verh. der Deutsch. Phys. Gesell., 15 seqq.) and others. A further theory of the photo-electric effect has been developed by Richardson (Phil. Mag. 23, 1912, p. 594; 24, 1912, p. 574), using statistical methods. This theory is not concerned with the actual mechanism of photo-electricity. It deduces laws from considerations of the interchange of energy, and is based on the assumption that the photo-electric substance is in thermal equilibrium, with complete radiation of equal intensity in every direction.

It is interesting to consider the relation between the total light-energy incident upon a photo-electric substance and the total energy represented by the emitted photo-electrons. This question has received the attention of Pohl and Pringsheim (Verh. der Deutsch. Phys. Gesell., 15, 1913, p. 173), who showed that the incident energy was always many times the energy of emission. In one case it was found that the total energy of the electrons emitted from a potassium surface was only some 2 per cent. or 3 per cent. of the light energy absorbed. It seems reasonable to suppose that the remaining energy is expended on electrons which do not escape from the photo-electric substance, but actually there is no evidence to show that the whole of the absorbed energy is utilised in the production of photo-electrons.

Theoretical considerations of photo-electric emission have had important effects upon the theory of light. While it is possible to explain the phenomena of diffraction and interference only by means of the wave theory of light, this theory is incapable of explaining the phenomenon of photo-electric emission, which indicates that light is composed of discrete particles, each of which is possessed of a certain definite amount of energy depending upon the wave-length of the light. These particles, which we have called photons, appear to have a definite existence and are evidently indivisible, since a fraction of a photon is never revealed by experiment. It can be shown experimentally that the direction of photo-electric emission under the action of plane-polarized light is affected by the polarization, so that the properties of light, in so far as polarization is concerned, depend upon the properties of the ultimate particles. These conditions can be explained only on the assumption of polarization of the photon, and lead to important considerations in the domain of quantum mechanics.

It appears from experiment that the liberation of photoelectrons is simultaneous with the incidence of light. Experiments in this connection by Stoletow (Phys. Rev., 1, 1892, p. 725) give no evidence for the existence of any time lag, and show that in the event of its existence it must be less than 10^{-3} second. Recent experiments by Lawrence and Beam (Phys. Rev., 29, 1927, p. 904) have shown that any time-lag which may exist must be less than 3×10^{-9} second, both when the light is started and stopped. In this respect, the photo-electric effect is preferable to the photo-conductive effect for many practical purposes.

By enclosing the light-sensitive substance in an evacuated container, into which a gas is introduced at a suitable pressure, it is possible considerably to increase the sensitivity and other characteristics of the emission. The series of experiments in this connexion, which was initiated by the early work of Elster and Geitel (Phys. Zeits., 14, 1913, p. 741) has resulted in a detailed knowledge of such effects, especially with the alkali metals, and has given rise to the gas-filled photo-electric cell, which has played such an important part in recent development. The sensitivity of such cells can be greatly increased by subjecting their light-sensitive element to a discharge in hydrogen. This also has the effect of increasing the sensitivity to red light; the increase in some cases being such that the same emission as an ordinary cell can be obtained from the specially prepared cell with light of nearly double the wave-length. A valuable account of the photo-electric properties of thin films of the alkali metals when subjected to these sensitising processes has recently been given by Campbell (Phil. Mag., 6, 1928, p. 633).

Applications of Photo-electricity.—The practical uses of the photo-electric effect were recognised at an early date, and have been applied extensively for a wide variety of scientific and engineering purposes. For certain of these purposes, where appreciable currents are required, it is necessary to employ a means of amplifying the photo-electric current, which is usually of the order of a few micro-amperes and is therefore much too minute for direct operation of even the most sensitive electro-magnetic apparatus. The triode valve, as developed for radio purposes, has been found to be of the greatest value as an amplifier of photo-electric currents, and may be said to have made possible the majority of practical applications of the photo-electric effect.

The early applications of photo-electric cells were mainly in connexion with purely scientific subjects, such as the various branches of photometry, in which the advantage of the sensitivity of the cells to changes of colour was soon recognised. Photo-electric cells were used many years ago by Harms (Phys. Zeits., 7, 1906, p. 585) for studying changes of light during a solar eclipse, by Nichols and Merritt (Phys. Rev., 24, 1907, p. 471) in the study of luminescence, by Richtmyer (Phys. Rev., 30, 1910, p. 394) for measuring the speed of photographic shutters and the decay of phosphorescence, by Elster and Geitel (Phys. Zeits., 11, 1910, p. 212; 13, 1912, p. 582) for measurements of illumination during solar and lunar eclipses, by Bergwitz (Phys. Zeits., 12, 1911, p. 1111) for the measurement of solar radiation, by Dember for the determination of the number of molecules in one gram molecule of a gas by observation of the absorption of sunlight in the atmosphere. Potassium cells were employed by Schulz (Astroph. Journal, 38, 1913, p. 187) for measuring the intensity of light from fixed stars. During these experiments, an easily readable deflection of an electrometer was obtained with $4{\cdot}19 \times 10^{-6}$ ergs of energy incident upon the cell. As an indication of the sensitivities obtainable, it may be remarked that as long ago as 1913 Elster and Geitel prepared cells having a sensitivity of 3×10^{-9} ergs per sq. cm. per second for blue light and 2×10^{-7} ergs per sq. cm. per second for orange light. The former value is actually more sensitive than the human eye.

Among the more practical applications of photo-electric cells, one of the most important is the automatic control of artificial illumination according to variations of daylight intensity. This principle has been applied to street lighting with considerable success. (O. Dworeck, "Fotozellensteurung für Strassenbeleuchtung-sanlagen," A. E. G. Mitteilungen, 3, März 1932, p. 103). Similar apparatus has been used extensively for the operation by automatic means of doors or gates on the approach of a moving object such as a person or vehicle. By means of an electro-magnetic counting device which is arranged to receive a current impulse when a beam of light focussed upon a photo-electric cell is interrupted momentarily, it is possible to count moving objects. On account of the very low time lag of the photo-electric unit, the speed of the counting can be very high, and in practice the limitation of this speed is determined by the mechanical features of the counting device. The question of time-lag in photo-electric cells has received considerable attention, in view of the large number of applications in which it is of importance (e.g., E. L. E. Wheatcroft, Phil. Mag., 12, 1931, p. 162).

Further practical applications include industrial photometry (G. T. Winch, Journal I.E.E., 68, 1930, p. 533; K. S. Gibson, Bur. Stds. Sci. Papers, No. 349, Oct. 1919; C. H. Sharp, Journ. Opt. Soc., America, 13, 1926, p. 304) in its various branches, spectrophotometry (C. Winther, Zeits. f. Elek., 19, 1913, p. 389; L. H. Tardy, Rev. d'Optique, 7, 1928, p. 189; A. H. Taylor, Journ. Frank Inst., 206, 1928, p. 241), and colorimetry (N. R. Campbell and H. W. B. Gardiner, Journ. Sci. Insts., 2, 1925, p. 177; A. C. Hardy, Journ. Opt. Soc., America, 18, 1929, p. 96).

In the printing industry, the photo-electric cell and its adjuncts have found numerous important applications. They include the automatic setting of type from typewritten copy, the preparation of half-tones by photo-electric scanning, without the use of acids, the control of register on web presses, automatic stopping in case of paper breakage, automatic counting, colour matching and measurement of opacity. (See the articles,

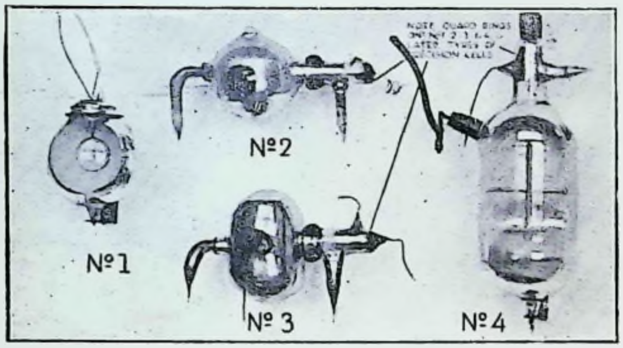

Fig. 2—Illustrating the development of photo-cells. [*Courtesy of General Electric Co.*

"Photo-cells reduce Costs in Printing Industries," Elec. World, 100, 1932, p. 547, and "Photo-Engravings now a matter of minutes," *ibid.*, p. 580).

Photo-electric methods have been applied extensively in ecological work for measurement of the penetration of light into water (V. E. Shelford and J. Kunz, Trans. Wisconsin Acad. Sci. Arts and Letters, 22, 1926, p. 283), and also for measuring the light-absorption of solutions (H. von Halban and H. Geigel, Zeits. f. phys. Chem., 96, 1920, p. 214; *ibid.*, 100, 1922, p. 208).

The colour sensitivity of the photo-electric cell has also rendered possible its use as a means of temperature control, and apparatus of this type operating with a high degree of accuracy has been applied to industrial heating processes (C. W. La Pierre, G.E. Review, 35, 1932, p. 403).

In view of the comparatively recent origin of these practical developments, it is evident that the possible uses of the photo-electric cell have been by no means fully explored, and there appears to be ample scope for further progress in this direction.

DEVELOPMENT OF PHOTO-ELECTRIC CELLS.

The evolution of various types of photo-electric cells is of considerable technical interest. During the early stages of development, most of the cells were of the type produced by Elster and Geitel, represented by No. 1 in *Fig. 2*. Its outstanding features are as follows:—

(a) A cathode of sensitised potassium on the wall of the cell;

(b) A large unshielded window;

(c) A gas filling of Argon.

At about this time there was considerable activity in the development of photo-electric cells for accurate photometry, for which it is necessary that the cell shall always give the same current for the same incident light. It was found that the irregularity of existing cells in this connexion was due to features (*b*) and (*c*), and in the elimination of this irregularity was developed the vacuum cell with a small window, represented by No. 2. It was later discovered that feature (*a*) was also undesirable, and No. 3 with a central plate cathode was next developed. This type of cell was used in the photometry of lamps and in photometric colour matching. Further improvements consisted in the use of a large window shielded by wire gauze, leading first to No. 4 and gradually to the modern type of cell, with sensitised potassium cathode as employed in the original types.

In the course of this development there was an increasing interest in the possibilities of the sound-film, which requires a high degree of sensitivity, as represented by the gas-filled cell,

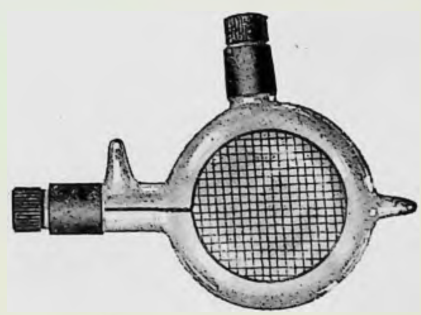

Fig. 3—Osram KG1 potassium gasfilled photo-cell (No. 5 in the series of development.) [*Courtesy of General Electric Co.*

rather than the accuracy obtainable with the vacuum cell. It was found that for sound film work the form of the electrodes was very important, and the gradual incorporation of the desired features resulted in the production of No. 5, shown in *Fig. 3*, which may be regarded as the first commercial type of cell, produced in large quantities for use with sound film equipments.

All the foregoing cells are sensitive to blue light and give a decreasing response as the red portion of the spectrum is approached. For certain applications it is desirable to have red sensitivity in preference to blue, and the means for producing this characteristic were discovered accidentally by observation of the fact that the grids of cells corresponding to type No. 5 were sensitive to red. This red sensitivity is due to the presence of a monomolecular film of potassium, which is formed on an oxidised metal when heated in potassium vapour owing to the reaction between the potassium and the oxide. This principle has been employed in the production of photometric photo-electric cells, in which the change of sensitivity with the colour of the light is very similar to that of the eye. Such cells have been employed extensively in the photometry of incandescent lamps.

In the meantime, a new type of cathode had been produced by heating oxidised silver in caesium vapour. This thin film caesium cathode was more red-sensitive than the potassium one,

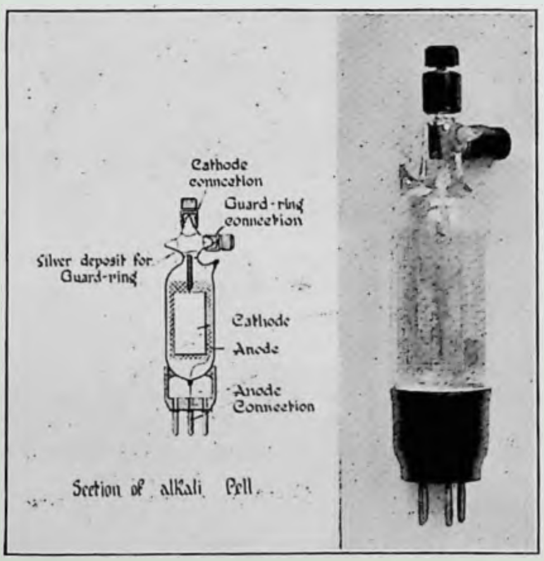

Fig. 4.—Modern commercial type of alkali metal photo-cell.
[*Courtesy of General Electric Co.*

and had the further advantage that a filling of argon could be employed. In the potassium cell it was not possible to use argon for the gas filling, for which hydrogen was employed, necessitating the provision of a palladium tube for replenishment as the hydrogen became gradually absorbed. With the advent of the thin film caesium cathode it was possible to dispense with these undesirable features and to develop a commercial type of cell having a wide range of useful application. Such a cell is illustrated in *Fig. 4*.

OTHER TYPES OF CELL.

Rectifier Type.

Reference must be made to what may be termed the dry rectifier type photo-electric cells, representing a recent development of considerable

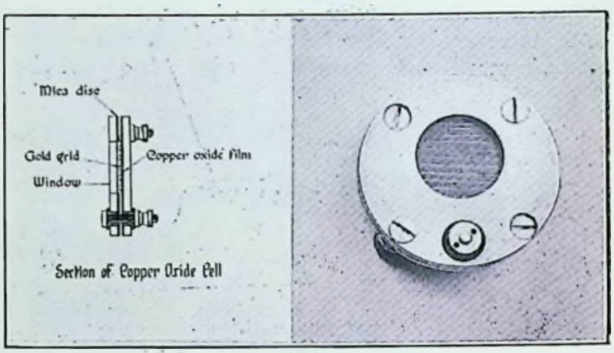

Fig. 5.—Dry rectifier type photo-cell, with copper oxide sensitive surface.
[*Courtesy of General Electric Co.*

promise. Most of the research work in this field has been carried out in Germany, where such cells are manufactured by several companies. In its original form, the rectifier cell consists of a layer or deposit of cuprous oxide on a copper plate forming one electrode. A conducting gauze is placed in contact with the oxide and serves as a second electrode, admitting light to the oxide surface as shown in *Fig. 5*.

The illumination results in the production of electrons, which flow in one direction only, from oxide to copper, resulting in a flow of current in the external circuit. It follows that with such cells there is no necessity for any external source of current or voltage; the current is produced simultaneously with the incidence of light, and the device does not rely upon a vacuum for its operation. As in the case of the photo-electric cell, there is a definite "threshold," and the cell is especially sensitive to red light.—(B. Lange, Phys. Zeits., 31, 1930, pp. 139-140, 964-969).

The foregoing principle has also been applied in a cell having a selenium layer as the photo-sensitive element, and which has been developed

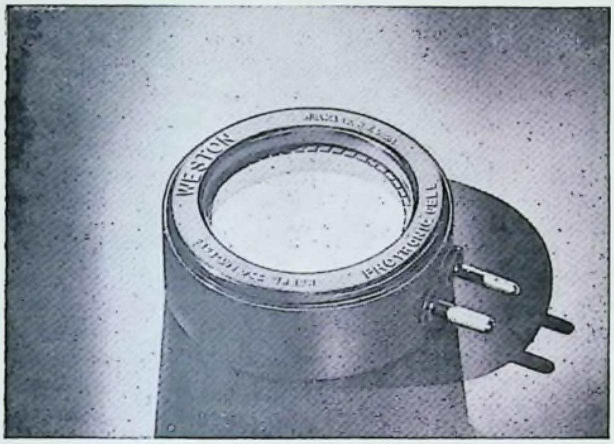

Fig. 6.—Modern rectifier type cell.
[*Courtesy of Weston Electrical Instrument Co. Ltd.*

extensively in Germany as the Selen-Sperrschicht-Photozelle (L. Bergmann, Phys. Zeits., 7, 1931, pp. 286-288). These cells are quite robust, and produce a relatively high current which may be multiplied by parallel connection of several cells. They are therefore very well suited to a wide range of practical applications. Serious limitations are, however, encountered in their response to rapid fluctuations of light intensity. At frequencies exceeding about 100 cycles, the response is very poor, decreasing with the frequency until at 1,000 cycles the response is only some 6 % of normal. This characteristic, due to the shunting effect of the internal capacity, imposes severe restrictions to the use of such cells in sound film and television work.

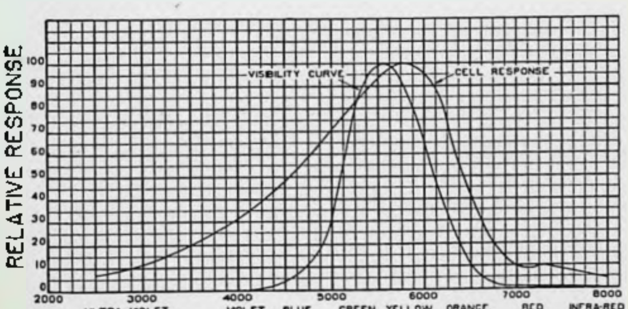

Fig. 7.—Spectral response wave of "Weston Photronic Cell."

[*Courtesy of Weston Electrical Instrument Co. Ltd.*

The general construction of a modern form of rectifier cell is shown in *Fig. 6*, while *Fig. 7* shows the spectral response obtained when using a quartz window up to 4,000 Ångstroms and a plain glass window above 4,000. From the experiments which have so far been carried out, it appears that the life of these cells is practically unlimited.

ELECTROLYTIC TYPE.

The electrolytic cell, illustrated in *Fig. 8* relies for its operation upon the Becquerel Effect and produces an e.m.f. when illuminated. It has the serious disadvantage of employing a liquid, such as cuprous oxide in a solution of potassium sulphate, and deteriorates with time, even when not in use. Like the dry rectifier cell, it requires no battery, but the output is very small, and this fact, coupled with the foregoing objections, has severely restricted its practical application. The theory of action has received comparatively scant attention, due to the inherent difficulties in this direction and the limited practical interest. (A useful discussion is contained in the work of Fleischer and Teichmann 1932, Section III., listed under No. 21 of the accompanying Bibliography).

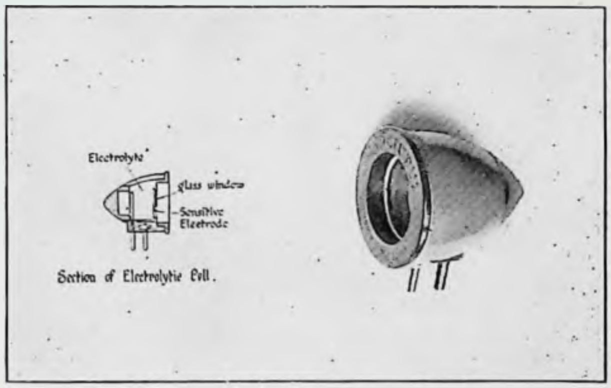

Fig. 8.—Electrolytic Cell.
[*Courtesy of General Electric Co.*

ACKNOWLEDGMENTS.

In conclusion, the author would like to thank the Research Laboratories of the General Electric Company for their courtesy in providing many illustrations of photo-cells, together with an account of their development work in this connexion. It is also a pleasure to acknowledge the information and illustrations supplied by the Weston Electrical Instrument Company relative to the rectifier type of cell.

BIBLIOGRAPHY.

1. E. Ruhmer, "Das Selen und seine Bedeutung für die Elektrotechnik," Berlin, 1902.
2. M. A. W. Sperling, "Beiträge zur Kenntnis der Selenzellen," Giessen (O. Kindt), 1908.

3. K. H. Moeller, "Ueber eine Verwendung der Selenzelle zur Tageslichtmessung," Kiel (Lüdtke u. Martens), 1909.
4. W. Jaenichen, "Lichtmessungen mit Selen," Berlin, 1914.
5. A. L. Hughes, "Photo-Electricity," Cambridge, 1914.
6. C. Ries, "Das Selen," München (Hubers Verlag), 1918.
7. T. W. Benson, "Selenium Cells : The construction, care and use of selenium cells, with special reference to the Fritts Cell," New York, 1919.
8. U. Bianchi, "Il selenio . . . .," Milano, 1919.
9. S. Wein, "Selenium Cells and how they are made," New York, 1919.
10. A. L. Hughes, "Report on Photo-Electricity," National Research Council, Washington, 1921.
11. E. E. Fournier d'Albe, "The Moon-Element : An introduction to the wonders of selenium," London, 1924.
12. H. S. Allen, "Photo-Electricity," 2nd Ed., London, 1925.
13. M. F. Doty, "Selenium : A List of References, 1817—1925," New York Public Library, 1927.
14. B. Gudden, "Lichtelektrische Erscheinungen," Berlin, 1928.
15. N. R. Campbell and D. Ritchie, "Photo-Electric Cells," London, 1929.
16. G. P. Barnard, "The Selenium Cell : Its properties and applications," London, 1930.
17. "Photo-Electric Cells and their Applications," London (Phys. Soc.), 1930.
18. V. K. Zworykin and E. D. Wilson, "Photo Cells and their Applications," New York, 1930; 2nd Ed., 1932.
19. A. L. Hughes and L. A. Dubridge, "Photo-Electric Phenomena," New York, 1932.
20. H. Simon and R. Suhrmann, "Lichtelektrische Zellen und ihre Anwendung," Berlin, 1932.
21. R. Fleischer and H. Teichmann, "Die lichtelektrische Zelle und ihre Herstellung," Leipzig, 1932.
22. R. C. Walker and T. M. Lance, "Photo-Electric Cell Applications," London, 1933.
23. H. Geffcken, H. Richter and J. Winckelmann, "Die lichtempfindliche Zelle als technisches Steurorgan," Berlin, 1933.
24. H. Geffcken and H. Richter, "Die Photozelle in der Technik," Berlin-Tempelhof, 1933.

DISCUSSION.

Dr. Tierney, D.Sc., the chairman, said that practical demonstrations of fundamental principles, such as the experiments performed by Mr. Denton, were of great value in enabling the student to assimilate his subject, especially after such an able theoretical survey as Mr. Windred had given. Moreover he considered that the study of photo-electricity would continue to increase in importance as more and more applications were found for it. In everyday life there were many photo-electric phenomena, of which the reactions associated with a green leaf were only one common example.

After thanking Mr. Windred, who expressed his appreciation, the chairman called upon the Editor of the *Journal*, Mr. W. G. W. Mitchell, to address the meeting on the question of the B.B.C. television transmissions, with a view to ascertaining members' views on the subject.

Mr. Mitchell asked whether it was the experience of members that the 30-line transmissions were improving in regard to "flicker" or whether this was still troublesome, whether members would wish to have the 30-line transmissions increased to either (*a*) 60-line or (*b*) 120-line pictures, and also whether they would prefer to see the number of lines increased while retaining the 30-line pictures or not.

Mr. Traub said that flicker had been one of the least of his problems, but this he attributed to the fact that he was only able to work with illumination of low intensity. He was of the opinion that a long range low definition service should be maintained indefinitely, although he considered that it might be advantageous to increase to 60 lines after an intermediate period in which 30-line and 60-line transmissions would take place alternately. The 60-line transmission, he suggested, might be made on a wavelength of about 180 metres and preferably from a special transmitter, since with the present relatively small demand for television programmes, the B.B.C. must obviously give preference to sound broadcasting from the existing stations. In a high definition system, he thought that 120 lines would provide satisfactory entertainment for a long time to come, and since at first it would not be possible to establish more than one experimental ultra short wave station, this should be located in London, where it would serve the maximum population within its limited range. Hence the necessity for the maintenance of a low definition transmitter, which could be more widely received. He asked whether the society as a whole would make any representations to the B.B.C. concerning the reduction in the number of transmissions.

Mr. Fairfield said that he had not been troubled with flicker, but in synchronising successfully he had experienced considerable difficulties, which had now been overcome by the use of a second phonic wheel. The entertainment value of the present transmissions he considered was good, and he hoped at some future date to record his results photographically.

Mr. Edwards said that he had been associated with the development of a 120-line cathode ray system, and he confirmed the severe difficulties encountered in the amplifier design and in the elimination of flicker. He suggested that television enthusiasts would be quite willing to pay more for their receiving licences in order to meet the transmitting expenses.

Mr. Friedman did not agree with the opinion of previous speakers, that flicker was less troublesome with low intensities of illumination, and he said that he had noticed a definite improvement in the B.B.C. transmissions since the introduction of additional photo-electric cells and especially since the international wavelength changes. He felt that with existing apparatus of a reasonable price, there was no entertainment value in 30-line reception. He did not doubt that our progress in television development was comparable with that of any other nation, especially since the recent publication of the results obtained by Mr. L. H. Bedford and his associates, of the Cossor Company. It was questionable, he thought, whether the country would appreciate high definition transmissions from films, when it was so easy to see the films themselves.

CURRENT LITERATURE.

V. K. Zworykin and E. D. Wilson, "Photo-cells and their Application," New York, John Wiley and Sons, Inc. [London: Chapman and Hall Ltd.] 1934, 2nd Ed., 2nd printing, pp. 348 + xv, 18/6 nett.

The fact that this is virtually the third edition of a book which first appeared only in 1930 affords the most practical possible demonstration that its general appeal has been extensive. The fact must not be overlooked that this is but one of several treatises on photo-cells which have appeared during recent years, so that the fairly rapid passage through three editions has a particular significance.

The title page informs us that the present edition is actually a reprint of the second edition, with revision and expansion of the chapter on Television. The book is divided into nineteen chapters, dealing with practically every phase of the theory, construction and application of all types of photo-cell.

In the first chapter we are given a brief historical review of development, commencing with the classical experiments of Herz in 1887 and leading to the important work of Elster and Geitel, which gave rise to the first commercial forms of photo-electric cell. In this chapter, one misses reference to the pioneer work of Smith and May, which is somewhat inconsistently included in the chapter on photo-conductive cells instead of finding its place in the historical introduction, since the phenomenon of photo-conductivity was discovered some years prior to Herz's experiments.

After a brief but well-annotated chapter on the general theories of radiation and the properties of matter, we are given in Ch. III. an outline of the characteristics of photo-sensitive films. This is followed by two excellent chapters on materials and apparatus for making photo-cells, containing much practical information which is absent from the majority of text books.

The next four chapters deal respectively with the vacuum, gas-filled, photo-conductive and photo-voltaic types of cell, and contain much useful information, especially concerning the various types of rectifier cell, representing a recent development of great promise. In the chapter on selenium cells, it would have been advisable to include an account of D'Albe's theory of the photo-conductive effect, but references to this work are given.

The next three chapters are devoted to a discussion of methods for utilising the various types of photo-cell, and in the course of this discussion the different types of amplifier are treated very thoroughly, except for a brief mention of gas-discharge tubes, which might well have been extended in view of the increasing uses of these devices. In discussing the thermionic amplifier, it is not made clear that the current given by Richardson's formula is the saturation value.

After a short chapter on special light-sensitive devices, including the photo-glow tube and the multiple cell, there is a comprehensive discussion of the use of the photo-cell in photometry and colorimetry, but in the space of some thirteen pages it is impossible to do justice to this important subject, especially as the ground covered ranges from stellar photometry to colour-matching and the photometry of the ultra-violet. The same might be said of the following chapter on "The Photo-cell in Sound Movies," which is dealt with in but ten pages.

Two further chapters of similar length are devoted to the photo-cell in facsimile transmission and in television. The latter opens with a discussion of the problem of scanning, passing to a brief description of the Nipkow arrangement and the modifications due to Ekström. The non-mechanical alternatives to these systems, utilising an electron beam as the scanning medium, are divided into three groups, of which the first, exemplified by the von Ardenne system is briefly described without any attempt towards completeness or detail. Slightly more attention is given to the special dissector cell developed by Farnsworth, but here again the description is barely adequate to convey any more than an understanding of the principles involved. By far the greater part of the chapter is devoted to a discussion of the theory and operation of the "Iconoscope," developed by Zworykin, one of the authors of the book, and representative of the third group, in which an electron beam is used to scan a photo-electric mosaic.

The penultimate chapter deals with the numerous miscellaneous applications of photo-cells, including illumination control, traffic control, counting, safety devices, time-recording by astronomical transit observations, and mechanical reading, in which the photophone of the late Fournier D'Albe is described. In the concluding chapter, the authors look into the future of photo-electric devices, indicating the theoretical possibilities of further development, of which the utilisation of infra-red sensitivity for purposes of nocturnal television is among the most interesting.

The book may be described as non-mathematical; this part of the argument being relegated to an appendix in all cases where more than a few simple formulæ are required. The Appendix also contains atomic and electronic constants, taken from Dushman's treatise on High Vacuum. Unfortunately, it appears that the same authority has not been employed elsewhere in the book, since the values given for the charge and mass of an electron on page 11 are out of accord with those on pp. 336-7 of the Appendix; the value of electronic charge given on p. 11 being quite inaccurate.

An outstanding feature of the book is that copious and useful references are appended to each chapter, but the practice adopted in the Biblography of quoting books without any indication of date or edition is not to be commended. The descriptive abilities of the authors leave little or nothing to be desired in the highly successful attempt they have made to present a clear, consistent and up-to-date account of their subject.

G.W.

"Television: Theory and Practice," J. H. Reyner [Chapman and Hall, London, 1934: 12/6].

The volume now under review is timely and most welcome. Timely because of the present revival of interest in Television, as exemplified by the Postmaster General's appointment of the Adivisory Committee now sitting, welcome because it attempts to bridge the very wide gap between the various popular expositions of the subject, and the publications of advanced workers in the Journals of learned Societies. Mr. Reyner has endeavoured to provide a balanced and reasonably comprehensive survey of the subject of Television, and his effort has undoubtedly been most successful.

Television brings together a great diversity of technical and even physiological problems, and the Table of Contents of the book is evidence of the fact that Mr. Reyner has not omitted to deal, if only comparatively briefly, with the multitude of topics which focus in Television; in other words, the book is an "all-round" study, from which no important aspect appears to be omitted. It begins with some general considerations of the nature of the problems of Television, which is well-defined by analogy as having for its object "to do for the eye what ordinary wireless reception does for the ear." Chapter II. is concerned with practical and mechanical problems, including mechanical scanning, synchronisation and the correct positioning of the received image. Chapter III., dealing with the physiological factors involved in viewing television pictures, is most interesting. One of the reasons why Television offers so many difficulties is that the eye is a much less gullible organ than the ear, and the chapter shows how exacting are the conditions imposed for the production of an image which shall be visually satisfactory.

In successive chapters Mr. Reyner considers some of the optical features of Television systems, including lens systems, electro-optical methods of light modulation, and discusses the important part played by photo-electric cells (which he invariably curtails to "photo-cells") in Television Transmission.

Three chapters are devoted to the applications of Cathode-Ray tubes in Television, both in transmission and in reception, and much valuable information is given on their practical operation. Mr. Reyner obviously believes that cathode-ray Television has great potentialities, particularly on the lines of some special system such as velocity-modulation, to which an additional section is allotted, and in which the method of operation of this rather complex system is clearly explained.

The chapter on "The Television Receiver" deals with the problems incidental to the radio reception of Television signals. The discussion includes the design of amplifiers capable of giving uniform amplification over a wide frequency range, and the necessity of avoiding relative phase-displacement of the various components of the signal during amplification is emphasised.

Other topics considered are Film Television, Colour Television, and a chapter is provided on "Special Systems," including Walton's "Scophony" system, with its curious echelon prisms, the H.M.V. system of "Zone Transmission" and the Marconi news-transmission system. Finally, there are three chapters on "Continental Practice" (i.e., principally German Television practice), "The American Idea" and "Television on Short Waves."

The book concludes with an interesting statement of the author's views on the possibilities of Television in the immediate future, and on the entertainment value of Television, and on these matters Mr. Reyner's views are entitled to respect. Incidentally, Mr. Reyner has elsewhere in the book a shrewd thrust at "the inadequate and over-exuberant information which has been published from time to time" concerning the progress of Television.

The book is definitely not exhaustive as regards Television systems and schemes, and it makes no pretence at describing every system of Television which has ever been proposed. Mr. Reyner has reserved his right to make a selection, and he has not hesitated to pick and choose. In his own words "only those examples have been included which are likely to point the way to future developments." With so much chaff and so comparatively little grain some discrimination is most desirable, but occasionally a little more information about certain of the systems which he has included (assuming it to be available, of course) would have been very acceptable. Occasionally, too, valuable space is given to topics which the more advanced reader may possibly consider to be redundant or too elementary. Moreover, the compression of so wide a study as that provided in the present volume, into a space of just under 200 pages has necessitated an economy of words and a conciseness of expressions which one feels is sometimes carried a little too far, as for example, in speaking of "a large light" when "a large amount of light" is clearly intended.

However, these are minor criticisms, and the book as a whole is eminently successful. It is to be heartily recommended as a valuable and much-needed addition to the literature of Television.

E.G.L.

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